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JOURNAL OF THE AERONAUTICAL SCIENCES

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The Theory of Isotropic Turbulence

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ABSTRACT

Two statistical properties of turbulence have been studied experimentally, the intensity and the scale. The intensity is measured by the root-mean-square fluctuation of the speed at a fixed point, and the scale by $\int_0^\infty R_y dy$, where R_y is the correlation between the velocity fluctuations at points along a line transverse to the direction of mean flow distant y apart.

A theory of the behavior of the intensity and scale of isotropic turbulence is developed along lines somewhat analogous to the theory of light and heat waves. It is explained how the turbulence may be described as a distribution of energy with wave length. It is then assumed, following a statement of Jeans with respect to the behavior of a non-conservative system of molecules, that the energy distribution tends to a definite statistical specification dependent on the law of dissipation. If the law of dissipation is known, this assumption is shown to provide a method of computing the energy distribution and of predicting the law of decay of the total energy and the change in the scale of the turbulence with time.

The dissipation is first assumed to be due to viscosity alone. The energy distribution obtained is

$$E_\lambda = K \frac{E_0}{\lambda_0} \left(\frac{\lambda}{\lambda_0}\right)^{-n} e^{\frac{-k\lambda_0^2}{\lambda^2}}$$

where E_0 is the total energy, λ is the wave length, λ_0 a length proportional to the scale, n and k undetermined constants, and K a numerical constant so adjusted that

$$\int_0^\infty E_\lambda d\lambda = E_0$$

The law of decay obtained is

$$\frac{E_0}{E_1} = \frac{{u_0}^2}{{u_1}^2} = \left(1 + \frac{120\pi^2\nu t}{k\lambda_0^2}\right)^{\frac{n-1}{2}}$$

and the variation of scale

$$\frac{{\lambda_1}^2}{{\lambda_0}^2} = 1 + \frac{120\pi^2\nu t}{k\lambda_0^2}$$

These formulae do not agree with the experimental results if λ_0 is assumed proportional to some linear dimension of the source of the turbulence.

The dissipation is then assumed to be due to stresses proportional to the square of the velocity. The energy distribution obtained is

$$E_\lambda = \frac{E_0}{L_0} \Big/ \left\{k(\lambda/L_0)^{-1/2} + K(\lambda/L_0)^{m/2}\right\}^2$$

where E_0 is the total energy, λ is the wave length, L a length proportional to the scale, m and k undetermined constants, and K a numerical constant so adjusted that

$$\int_0^\infty E_\lambda d\lambda = E_0$$

The law of decay obtained is

$$\frac{E_0}{E_1} = \frac{{u_0}^2}{{u_1}^2} = \left(1 + \frac{C\,u_0 t}{L_0}\right)^{\frac{2(m-1)}{m+1}}$$

and the variation of scale

$$\frac{L_1}{L_0} = \left(1 + \frac{C\,u_0 t}{L_0}\right)^{\frac{2}{m+1}}$$

The formulae for the decay and the variation of scale check the experimental data. Comparison with the formulae for viscous dissipation shows identity, if it is assumed that $\frac{C\,u_0}{L_0} = \frac{120\pi^2\nu}{k\lambda_0^2}$. This is a form of Taylor's relation for the dependence of the wave length of the micro-turbulence which is dissipated by viscosity on the intensity and scale of the macro-turbulence whose energy is converted by "collisions" to micro-turbulence.

The second pair of formulae may also be obtained by dimensional reasoning, the procedure being related to von Kármán's concept of similarity of the turbulent flow pattern.

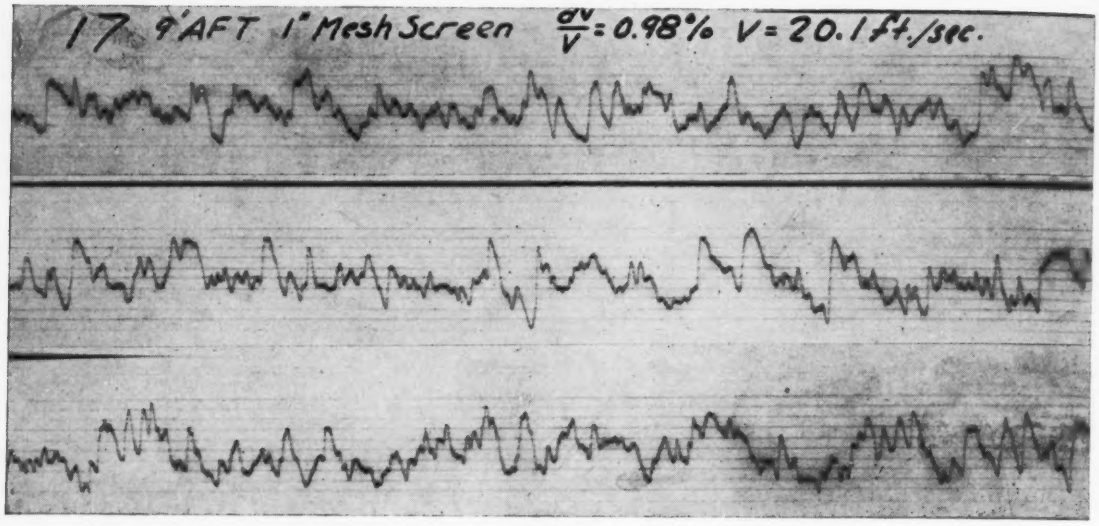


FIG. 1. Oscillograph record of velocity fluctuations 9 feet behind 1-inch mesh screen. Each strip of film corresponds to a time interval of approximately 0.34 second.

THE early theories of turbulence developed by Prandtl and Taylor were based on the concept of air masses moving with respect to the mean flow like the molecules of a gas. The scale of the turbulent motion was characterized by the mixing length, a length analogous to the mean free path of the kinetic theory of gases. A little over a year ago Taylor put forward his statistical theory of turbulence, in which the scale of the turbulence was defined in terms either of the correlation between the velocity of a given fluid particle at one time and the velocity of the same particle at a later time or in terms of the correlation between the velocity fluctuations at points along a line transverse to the direction of mean flow. If, for example, the correlation R_y between the velocity fluctuations at two points distant y apart has been measured for various values of y, the scale may be defined as $\int_0^\infty R_y dy$, provided of course that the integral has a finite value. The scale so defined is a statistical measure of the average distance over which the velocity fluctuations remain approximately in phase, in other words, a measure of the average size of the eddies present.

Experimental studies of isotropic turbulence, in which the fluctuations are perfectly random in direction with no correlation between components in various directions,[1] have been carried out at the National Bureau of Standards with the cooperation and financial support of the National Advisory Committee for Aeronautics, and the preliminary results were reported at the 1936 Annual Meeting of the Institute of Aeronautical Sciences.[2] A complete report is now in press and will be released as Technical Report No. 581 of the National Advisory Committee for Aeronautics. The results are interpreted in that report in terms of Taylor's theory.

The measurements were made on turbulence induced in a wind-tunnel airstream by means of wire screens. At a distance of 75 or 100 wire diameters downstream, the turbulence was shown to be isotropic. The mean flow apparently plays no part in determining the decay but serves to sweep the turbulent wave pattern past a fixed point, giving rise to a frequency pattern in the familiar oscillograph record of the fluctuation at a fixed point (Fig. 1). A given time interval t corresponds to the travel of the pattern a distance Ut downstream where U is the mean speed. It is probable that the results obtained could be duplicated in a large chamber with no mean flow, if some means could be devised to produce a uniformly distributed turbulence in the inclosure and to measure the intensity and scale quickly as the decay took place.

Taylor's theory represents a movement from the "atomic" or discontinuous to a continuous representation of turbulence and again emphasizes the desirability of statistical treatment. Progress will probably continue in this direction. For, if one examines smoke pictures of turbulent flow, the motion of tobacco smoke in the disturbed air of a room, or an oscillograph record of the velocity fluctuations at a point in a turbulent airstream, the vast amount of detail and irregularity leads to bewilderment rather than to clarification of fundamental concepts. Two statistical properties, the intensity and the scale, have been recognized and

[1] This clause is not intended as a rigorous mathematical definition of isotropic turbulence. A complete definition requires the statement that the average value of any function of the velocity components is invariant with respect to rotation of the axes of reference.

[2] Hugh L. Dryden, *Experimental Techniques for Studying Turbulent Air Flow*, Journal of the Aeronautical Sciences, Vol. 3, No. 5, p. 173, March, 1936.

studied experimentally. In the smoke picture or oscillograph record, the average speed of the smoke particles or the average velocity fluctuation may remain nearly constant in time although the instantaneous values vary widely. By custom the root-mean-square average fluctuation has been adopted as a measure of intensity. The smoke picture shows a limited range of sizes of eddies and the oscillograph record contains the suggestion of a principal frequency. The method of obtaining a definite numerical scale has been discussed previously.

This characterization of the turbulent motion by the two quantities, intensity and scale, corresponds to the characterization of the molecular motion of a gas by temperature and mean free path. A somewhat broader treatment appears to be easily possible, namely, to take account of the fact that eddies of various sizes are present and to consider the distribution of intensity with size. This procedure is analogous to the classical treatment of light and heat waves, for example, in the theory of light and black body radiation, and forms a suitable supplement to the procedure based on statistical mechanics, which examines the mechanism in more detail and from another point of view.

Suppose harmonic analyses were made of a large number of successive oscillograph records taken at the same point using a fundamental frequency which is very low compared to the "principal" frequency of the turbulent fluctuations. Statistically there would be obtained a variation of intensity with frequency which in the limit of a very low fundamental frequency would approach a continuous distribution. Experimentally, the energy distribution might be obtained by the use of electric filters which would perform the same function as the dispersing element of a spectrometer in analyzing optical radiation.

Let the analysis of one record give the result

$$u = \sqrt{2}\, u_1 \cos(2\pi f t - \alpha_1) + \sqrt{2}\, u_2 \cos(4\pi f t - \alpha_2) + \sqrt{2}\, u_3 \cos(6\pi f t - \alpha_3) + \text{etc.}$$

where u is the instantaneous velocity, f is the fundamental frequency, and the $\sqrt{2}$ is introduced so that the u's are root-mean-square time averages.

Then

$$u^2 = 2u_1^2 \cos^2(2\pi f t - \alpha_1) + 2u_2^2 \cos^2(4\pi f t - \alpha_2) + 2u_1 u_2 \cos(2\pi f t - \alpha_1) \cos(4\pi f t - \alpha_2) + \text{etc.}$$

The mean-square time average would be given by

$$\overline{u^2} = u_1^2 + u_2^2 + u_3^2 + \text{etc.}$$

and the mean-square average of a large number of records in which u_1, u_2, etc., show statistical fluctuations by

$$\overline{u^2} = \overline{u_1^2} + \overline{u_2^2} + \overline{u_3^2} + \text{etc.}$$

If now the fundamental frequency is made infinitely small and the distribution considered as a continuous function of the now variable frequency f

$$\overline{u^2} = \int_0^\infty \overline{u_f^2}\, df$$

where it must be noted that u_f is not a velocity and does not have the dimensions of velocity but of velocity divided by square root of frequency. Considered as a distribution with wave length λ in space at any instant rather than as a distribution in time at any point

$$\overline{u^2} = \int_0^\infty \overline{u_\lambda^2}\, d\lambda \quad \text{where } \overline{u_\lambda^2}\, d\lambda = \overline{u_f^2}\, df$$

Similarly

$$du = -2\sqrt{2}\,\pi u_1 f \sin(2\pi f t - \alpha_1) dt - 4\sqrt{2}\,\pi u_2 f \sin(4\pi f t - \alpha_2) dt, \text{ etc.}$$

dividing by dx

$$\frac{du}{dx} = -2\sqrt{2}\,\pi u_1 f \sin(2\pi f t - \alpha_1) \frac{dt}{dx} - 4\sqrt{2}\pi u_2 f \sin(4\pi f t - \alpha_2) \frac{dt}{dx}, \text{ etc.}$$

Since $f\dfrac{dt}{dx} = \dfrac{1}{\lambda_1}$, $2f\dfrac{dt}{dx} = \dfrac{1}{\lambda_2}$, etc.

$$\overline{\left(\frac{du}{dx}\right)^2} = 4\pi^2 \frac{u_1^2}{\lambda_1^2} + 4\pi^2 \frac{u_2^2}{\lambda_2^2} + \text{etc.}$$

or for a large number of records with continuous energy distribution

$$\overline{\left(\frac{du}{dx}\right)^2} = 4\pi^2 \int_0^\infty (\overline{u_\lambda^2}/\lambda^2) d\lambda$$

Introducing $E = {}^1/_2 \rho \overline{u^2}$ and $E_\lambda = {}^1/_2 \rho \overline{u_\lambda^2}$

$$E = \int_0^\infty E_\lambda d\lambda \tag{1}$$

$$\overline{\left(\frac{du}{dx}\right)^2} = 8\pi^2 \int_0^\infty (E_\lambda/\lambda^2) d\lambda \tag{2}$$

Thus the turbulence may be characterized by a function E_λ of the wave length λ such that the energy of the turbulence per unit volume in wave lengths between λ and $\lambda + d\lambda$ is $E_\lambda d\lambda$. The total energy per unit volume or intensity is $\int_0^\infty E_\lambda d\lambda$.

At present, experimental difficulties preclude the direct measurement of the energy distribution. Until such data are available, some speculation may be useful. Jeans in his classical work, *The Dynamical Theory of Gases*, points out that whereas in conservative systems (*i.e.*, those without dissipation) the velocity distribution among the molecules is independent of the constitution of the molecules, such is not the case in a dissipative system. However (1st edition, p. 188),

"out of a number of systems which have a given value for the energy, this value being sufficiently low, and have had their energy reduced from higher values by dissipation, the systems meanwhile being unaffected by external disturbance, all except an infinitesimal fraction will have the same statistical specification." This statistical specification will be determined by the dissipation function.

Suppose, then, that this reasoning applies to isotropic turbulence and hence that after some decay the energy will be distributed among different wave lengths according to a law which depends on the dissipation function. In the remaining decay, assume that the distribution curves remain affine, *i.e.*, of similar shape, the only variable parameters being the total energy and some reference wave length. The reference wave length may be assumed to be proportional to the wave length at which the energy is a maximum.

The problem may be formulated mathematically as follows: [3]

At some specified time designated $t = 0$, the energy distribution is to be given by a function $f(\lambda/\lambda_0)$ where λ_0 is a reference wave length. At some later time $t = t_1$, the distribution is to be given by $\frac{1}{A} f(\lambda/\lambda_1)$, where A is a factor dependent on the time interval, λ_1 is the new reference wave length, also dependent on the time interval, and f is the same function as before. The total energy E_0 per unit volume at $t = 0$ equals $\int_0^\infty f(\lambda/\lambda_0)d\lambda = \lambda_0 \int_0^\infty f(\lambda/\lambda_0)d(\lambda/\lambda_0)$ by Eq. (1) and the total energy E_1 per unit volume at $t = t_1$ equals $\frac{\lambda_1}{A}\int_0^\infty f(\lambda/\lambda_1)d(\lambda/\lambda_1)$. Hence

$$A = \frac{E_0\lambda_1}{E_1\lambda_0} \tag{3}$$

Compare the distributions when plotted against λ/λ_0. The function $\frac{1}{A} f(\lambda/\lambda_1)$ considered as a function of λ/λ_0 will be designated $f_1(\lambda/\lambda_0)$. The later distribution must have resulted from the action of the dissipation which has the effect of multiplying each ordinate of the old distribution by a function $\phi\left(\frac{\lambda}{\lambda_0}, t\right)$.

Therefore

$$f_1(\lambda/\lambda_0) = f(\lambda/\lambda_0)\phi\left(\frac{\lambda}{\lambda_0}, t\right)$$

But by definition

$$f_1(\lambda/\lambda_0) = \frac{1}{A} f(\lambda/\lambda_1)$$

Hence

$$f(\lambda/\lambda_1) = Af(\lambda/\lambda_0)\phi\left(\frac{\lambda}{\lambda_0}, t\right)$$

or

$$f(ar) = Af(r)\phi(r, t)$$

where a is written for λ_0/λ_1 and r for λ/λ_0.

Considering t as a function of a rather than a as a function of t and setting $A\phi(r, t) = g(r, a)$, there follows

$$f(ar) = f(r)g(r, a) \tag{4}$$

Differentiating with respect to a, denoting

$$\frac{\partial g(r, a)}{\partial a} \text{ by } g'(r, a)$$

$$rf'(ar) = f(r)g'(r, a)$$

whence

$$\frac{f'(ar)}{f(ar)} = \frac{1}{r}\frac{g'(r, a)}{g(r, a)} \tag{5}$$

The necessary and sufficient condition that there exists a function f corresponding to a given g which satisfies Eq. (4) is that $\frac{1}{r}\frac{g'}{g}$ should be a function of ar only. If the implicit functions of a occurring in $\frac{1}{r}\frac{g'}{g}$ are adjusted so that the expression is a function of ar only, Eq. (5) gives a differential equation for the determination of f.

Consider as an example the dissipation by the action of viscosity. Taylor has shown that the rate of dissipation $\overline{W}$ by viscosity in isotropic turbulence is given by

$$\overline{W} = -\frac{dE}{dt} = 15\mu\overline{\left(\frac{du}{dx}\right)^2} \tag{6}$$

where μ is the viscosity. Substituting for $\overline{\left(\frac{du}{dx}\right)^2}$ its value as given by Eq. (2)

$$\overline{W} = 120\pi^2(\mu/\rho)\int_0^\infty E_\lambda/\lambda^2)d\lambda \tag{7}$$

The total dissipation may therefore be regarded as made up of the sum of partial dissipations $W_\lambda = -\frac{dE_\lambda}{dt}$ associated with each wave length, setting $\overline{W} = \int_0^\infty W_\lambda d\lambda$, where

$$W_\lambda = -\frac{dE_\lambda}{dt} = \frac{120\pi^2\nu E_\lambda}{\lambda^2}$$

ν being written for the kinematic viscosity μ/ρ. Integrating this expression

$$E_\lambda = (E_\lambda)_0 e^{\frac{-120\pi^2\nu t}{\lambda^2}}$$

whence

$$\phi\left(\frac{\lambda}{\lambda_0}, t\right) = e^{\frac{-120\pi^2\nu t}{\lambda^2}}$$

[3] Acknowledgment is made to L. B. Tuckerman for assistance in this formulation.

Hence the function $g(r, a)$ is of the form Ae^{B/r^2}, where

$$B = \frac{-120\pi^2\nu t}{\lambda_0^2} \quad \text{and} \quad A = \frac{E_0\lambda_1}{E_1\lambda_0}$$

as previously derived. A and B are functions of a, which is the symbol for λ_0/λ_1.

Applying the general method

$$\frac{1}{r}\frac{g'}{g} = \frac{A'}{Ar} + \frac{B'}{r^3} \tag{8}$$

The most general choice of A and B which makes this expression a function of ar alone is:

$$A = ha^{-n}$$

$$B = -\frac{k}{a^2} + m \tag{9}$$

the minus signs being used to make n and k positive quantities as will appear later.

Substituting Eq. (9) in Eq. (8)

$$\frac{1}{r}\frac{g'}{g} = -\frac{n}{ar} + \frac{2k}{(ar)^3}$$

But

$$\frac{1}{r}\frac{g'}{g} = \frac{f'(ar)}{f(ar)} = \frac{d \log f(ar)}{d(ar)}$$

The differential equation for f is accordingly

$$\frac{d \log f(ar)}{d(ar)} = \frac{2k}{a^3r^3} - \frac{n}{ar}$$

On integration

$$\log f(ar) = -\frac{k}{a^2r^2} - n \log(ar) + \log C$$

or

$$f(ar) = C(ar)^{-n} e^{-\frac{k}{a^2r^2}}$$

Since the energy is finite, n and k are positive. The negative signs were introduced earlier to make n and k positive. The constant C is determined by the condition

$$\int_0^\infty f(ar)d\lambda = \int_0^\infty f(\lambda/\lambda_1)d\lambda = E$$

which yields

$$C = 2Ek^{\frac{1-n}{2}}/\lambda_1 \Gamma\left(\frac{n-1}{2}\right)$$

If $2k^{\frac{1-n}{2}}/\Gamma\left(\frac{n-1}{2}\right)$ is set equal to K, the distribution is given by the expression

$$E_\lambda = K\frac{E}{\lambda_1}\left(\frac{\lambda}{\lambda_1}\right)^{-n} e^{-\frac{k\lambda_1^2}{\lambda^2}} \tag{10}$$

The maximum energy is found when $f'(ar) = 0$, *i.e.*, when $na^2r^2 = 2k$. The wave length $\lambda_{max.}$ is given by

$$\lambda^2_{max.} = \frac{2k\lambda_1^2}{n} \tag{11}$$

Substituting the values of A and B in Eq. (9)

$$\frac{E_0\lambda_1}{E_1\lambda_0} = h\left(\frac{\lambda_0}{\lambda_1}\right)^{-n} \quad \text{and} \quad -\frac{120\pi^2\nu t}{\lambda_0^2} = -k\frac{\lambda_1^2}{\lambda_0^2} + m$$

Since $\lambda_1 = \lambda_0$ and $E_1 = E_0$ at $t = 0$, $h = 1$ and $k = m$

$$\frac{\lambda_1^2}{\lambda_0^2} = 1 + \frac{120\pi^2\nu t}{k\lambda_0^2} \tag{12}$$

$$\frac{E_0}{E_1} = \left(\frac{\lambda_0}{\lambda_1}\right)^{1-n} = \left(1 + \frac{120\pi^2\nu t}{k\lambda_0^2}\right)^{\frac{n-1}{2}} \tag{13}$$

This procedure has given an energy distribution, Eq. (10), corresponding to the assumed dissipation, Eq. (6), and also formulae, Eq. (13) and Eq. (12), for the decay of the total energy and for the change in scale of the turbulence with time. A comparison with experiment shows that these formulae cannot be correct, if λ_0 is proportional to the scale of the screen producing the turbulence and independent of wind speed. For if $\lambda_0 = bM$, Eqs. (12) and (13) become in terms of x $(= Ut)$

$$\frac{\lambda_1^2}{b^2M^2} = 1 + \frac{120\pi^2\nu Ux}{kb^2M^2}$$

and

$$\frac{E_0}{E_1} = \left(1 + \frac{120\pi^2\nu Ux}{kb^2M^2}\right)^{\frac{n-1}{2}}$$

and the change of intensity and scale would depend on the mean speed U and the scale of the screen M as well as on the ratio x/M. Experiment shows the changes to depend only on x/M and not on U at all or on M apart from the ratio x/M. Hence λ_0 must depend on U or the mechanism of decay cannot be that assumed in Eq. (6).

The mechanism assumed in Eq. (6) was viscous dissipation, the shearing stresses being proportional to the first power of the velocity. The other type of dissipation frequently encountered in fluid mechanics is that in which the shearing stresses are proportional to the square of the velocity. In such a system the rate of dissipation is proportional to the product of the densito by the cube of the velocity and inversely proportional to some linear dimension defining the scale of the system. Accordingly as a second example of the use of the general method of obtaining the energy distribution, assume that the dissipation of the energy in a particular wave length is an independent process for which

$$W_\lambda = -\frac{dE_\lambda}{dt} = \tfrac{1}{2}\rho\frac{du_\lambda^2}{dt} = \frac{C'\rho u_\lambda^2}{\sqrt{\lambda}} \tag{14}$$

Note that from its definition ($^1/_2 \rho \int_0^\infty u_\lambda^2 d\lambda = \int_0^\infty E_\lambda d\lambda = E = {}^1/_2 \rho \overline{u^2}$), u_λ has the dimensions of velocity divided by square root of length. Hence the form selected for W_λ to make C' a non-dimensional constant. In the following analysis, the reference wave lengths will be designated L_0 and L_1 to distinguish them from λ_0 and λ_1 in a later comparison of this analysis with the preceding one. Integrating Eq. (14) with respect to the time

$$\frac{1}{u_\lambda} - \frac{1}{(u_\lambda)_0} = \frac{C' t}{\sqrt{\lambda}}$$

or

$$\frac{E_\lambda}{(E_\lambda)_0} = \frac{1}{\left(1 + \frac{C'(u_\lambda)_0 t}{\sqrt{\lambda}}\right)^2} \tag{15}$$

To obtain non-dimensional constants throughout, it is convenient to take $\frac{(E_\lambda)_0 L_0}{E_0}$, where $E_0 (= {}^1/_2 \rho u_0^2)$ is the total energy at $t = 0$, as $\mathrm{f}(r)$. The function $\mathrm{g}(r, a)$ is then of the form

$$\mathrm{g}(r, a) = A \Big/ \left(1 + B\sqrt{\frac{\mathrm{f}}{r}}\right)^2$$

where $B = \frac{C' u_0 t}{L_0}$, $A = \frac{E_0 L_1}{E_1 L_0}$ as before and f is understood to be $\mathrm{f}(r)$.

Applying the general method, there is obtained after a computation in which after the differentiations are performed, there is substituted for f its value as obtained by solving

$$\mathrm{f}(ar) = \mathrm{fg}(r, a) = A\mathrm{f}/ (1 + B\sqrt{\mathrm{f}/r})^2$$

$$\frac{1}{r}\frac{\mathrm{g}'}{\mathrm{g}} = \frac{A'}{Ar} - \frac{2B'}{\sqrt{Ar}}\sqrt{\mathrm{f}(ar)} \tag{16}$$

The most general choice of A and B which makes this expression a function of ar alone is:

$$A = ha^{-m} \text{ and } B = ka^{-\frac{(m+1)}{2}} + l$$

Since $A = 1$ and $B = 0$ when $a = 1$, $h = 1$, and $k = -l$. Substituting $A = a^{-m}$ and $B = k(a^{-\frac{(m+1)}{2}} - 1)$ in Eq. (16) there is obtained

$$\frac{1}{r}\frac{\mathrm{g}'}{\mathrm{g}} = -\frac{m}{ar} - \frac{k(m+1)\sqrt{\mathrm{f}(ar)}}{(ar)^{3/2}}$$

But this expression must equal

$$\frac{\mathrm{f}'(ar)}{\mathrm{f}(ar)} = \frac{d \log \mathrm{f}(ar)}{d(ar)}$$

The resulting differential equation can be brought into integrable form by setting $\mathrm{f}(ar) = u^2(ar)$, $\log (ar) = w$, whence

$$2\frac{du}{dw} = -(m+1)u + k(m+1)u^2$$

and the variables are separated.

The solution in terms of the original variables is

$$\mathrm{f}(ar) = \{k(ar)^{-1/2} + K(ar)^{m/2}\}^{-2}$$

or

$$E_\lambda = \frac{E_0}{L_0} \Big/ \{k(\lambda/L_0)^{-1/2} + K(\lambda/L_0)^{m/2}\}^2$$

where E_0 is the total energy, λ is the wave length, L a length proportional to the scale, m and k undetermined constants, and K is a constant of integration so adjusted that $\int_0^\infty E_\lambda d\lambda = E_0$.

From the relations found for A and B

$$\frac{E_0 L_1}{E_1 L_0} = \left(\frac{L_0}{L_1}\right)^{-m} \text{ and } \frac{C' u_0 t}{L_0} = k\left[\left(\frac{L_0}{L_1}\right)^{-\frac{(m+1)}{2}} - 1\right]$$

or writing $\frac{C'}{k} = C$

$$\left(\frac{L_1}{L_0}\right)^{\frac{m+1}{2}} = 1 + \frac{C u_0 t}{L_0} \tag{17}$$

$$\frac{E_0}{E_1} = \frac{u_0^2}{u_1^2} = \left(\frac{L_0}{L_1}\right)^{1-m} = \left(1 + \frac{C u_0 t}{L_0}\right)^{\frac{2(m-1)}{m+1}} \tag{18}$$

It follows

$$\frac{u_0 L_1}{u_1 L_0} = 1 + \frac{C u_0 t}{L_0} \tag{19}$$

Comparing Eq. (19) with Eq. (12), and Eq. (18) with Eq. (13), the results are formally identical if

$$n = \frac{5m - 3}{m + 1}, \quad \frac{C u_0}{L_0} = \frac{120\pi^2\nu}{k\lambda_0^2}, \text{ and } \frac{C u_1}{L_1} = \frac{120\pi^2\nu}{k\lambda_1^2}.$$

This relation in slightly different form and its interpretation were first given by Taylor.[4] The body of fluid which is in a state of turbulence may be conceived to be filled with rather large eddies which move to and fro in an irregular manner losing energy by collisions according to the law expressed by Eq. (14). The energy of this macro-turbulence is redistributed among smaller eddies resulting from the collisions, and this micro-turbulence is dissipated by the action of viscosity according to Eqs. (6) and (13). Both processes occur simultaneously with a quasi-steady state. The rate of dissipation of the micro-turbulence by viscosity is equal to the rate of dissipation of the macro-turbulence by collisions, the energy in both forms decreasing continuously. The energy per unit volume in the micro-turbulence is equal to the energy

[4] Proc. Roy. Soc. London, Vol. 151, pp. 421–478, 1935.

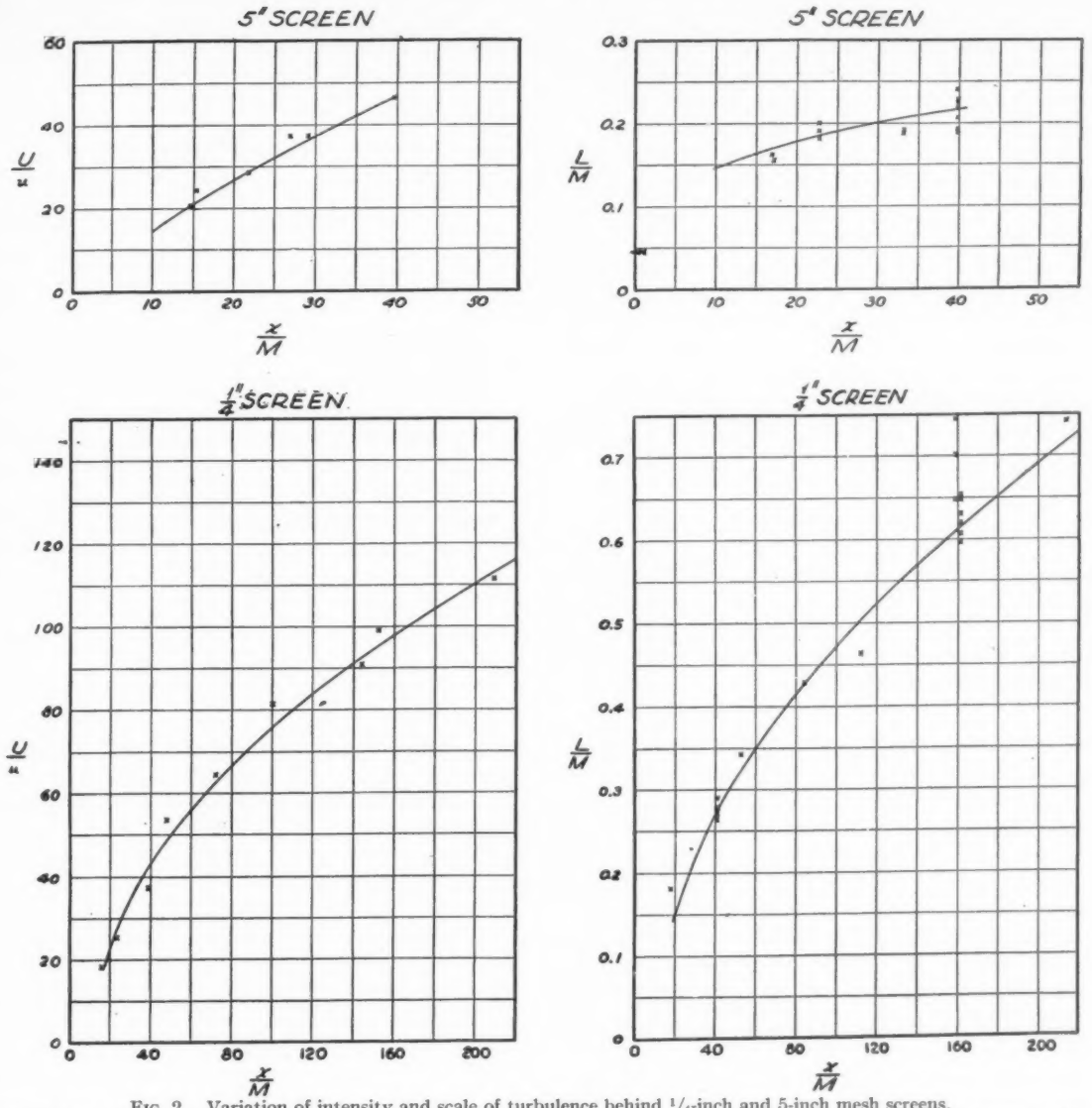


FIG. 2. Variation of intensity and scale of turbulence behind 1/4-inch and 5-inch mesh screens. The solid lines are theoretical curves with $m = 3$ ($n = 3$) for the 1/4-inch screen and $m = 7$ ($n = 4$) for the 5-inch screen. The points represent experimental values.

per unit volume of the macro-turbulence.[5] The equation $\lambda_0^2 = \frac{120\pi^2\nu L_0}{kC\,u_0}$ gives the relation between the effective wave length[6] of the micro-turbulence to the intensity and scale of the macro-turbulence.

The non-dimensional ratio $\frac{\nu L_0}{u_0\lambda_0^2}$ may be written $\frac{\mu u_0^2}{\lambda_0^2}\frac{L_0}{u_0}$ divided by ρu_0^2 and hence may be interpreted as proportional to the ratio of the total dissipation in the "mean free time" $\frac{L_0}{u_0}$ to the initial energy $\frac{1}{2}\rho u_0^2$. The effective wave length of the micro-turbulence adjusts itself so that this ratio remains constant.

The rate of decay and the change of scale as given by Eqs. (18) and (19) are in good agreement with the experimental results obtained at the National Bureau of Standards (Fig. 2). The exponent m is found to vary to some extent with the screen used to produce the turbulence, probably because the screens were not exactly geometrically similar. For the 1/4-inch screen, $m = 3$ (corresponding to $n = 3$) gives a good fit and

[5] Since the rates of dissipation are equal, the energy per unit volume of the macro-turbulence can only differ from that of the micro-turbulence by a constant amount. Since, however, both approach zero as a limit, the constant must be zero.

[6] As previously stated, $\lambda_0^2 = \frac{n}{2k}\lambda^2_{\max.}$, where $\lambda_{\max.}$ is the wave length at which E_λ is a maximum. Taylor's λ, defined in terms of the dissipation, is proportional to λ_0 or $\lambda_{\max.}$

for the 5-inch screen, $m = 7$ (corresponding to $n = 4$). The law derived by Taylor on the assumption that L remained constant as the turbulence decayed may be obtained by setting $m = \infty$ or $n = 5$, or regarded as an approximate form obtained for small values of t.

The theory which has been outlined bears an interesting relation to von Kármán's theory of uni-directional turbulent flow which was based on the concept of similarity of the turbulent flow pattern; for Eqs. (17) and (18) may be obtained from considerations of similarity, as should be obvious from the initial assumption of similar energy distribution curves. If one assumes that the scale L and intensity u are determined only by the initial values L_0 and u_0 at $t = 0$ and the time interval t, application of the principles of dynamical similarity gives the uninteresting result

$$\frac{L}{L_0} = \mathrm{f}\left(\frac{u_0 t}{L_0}\right) \text{ and } \frac{u}{u_0} = \mathrm{g}\left(\frac{u_0 t}{L_0}\right)$$

where f and g are unknown functions. But if one assumes that du/dt, the rate of change of intensity, and dL/dt, the rate of change of scale, are determined solely by the values of L and u (*i.e.*, that viscosity and upstream conditions have no influence), it follows from dimensional reasoning that

$$L\frac{d\frac{1}{u}}{dt} = A \quad \text{and} \quad \frac{1}{u}\frac{dL}{dt} = B \tag{20}$$

where A and B are numerical constants.

On integration there results

$$\frac{L}{u} = \frac{L_0}{u_0} + (A + B)t$$

$$\frac{u_0}{u} = \left[1 + \frac{(A + B)u_0 t}{L_0}\right]^{\frac{A}{A+B}}$$

$$\frac{L}{L_0} = \left[1 + \frac{(A + B)u_0 t}{L_0}\right]^{\frac{B}{A+B}}$$

which are identical with Eqs. (18) and (17) if $A + B = C$ and $m = \dfrac{2A + B}{B}$ or $A = \dfrac{1 - m}{1 + m}C$ and $B = \dfrac{2C}{1 + m}$.

The differential Eqs. (20) reveal an interesting but expected property of the solution that the initial u and L may be selected to correspond to any time. If t is measured arbitrarily, the values of L_1 and u_1 at $t = t_1$ and L_2 and u_2 at $t = t_2$ are related by the formulae:

$$\frac{u_1}{u_2} = \left[1 + \frac{(A + B)\,u_1(t_2 - t_1)}{L_1}\right]^{\frac{A}{A+B}}$$

$$\frac{L_2}{L_1} = \left[1 + \frac{(A + B)\,u_1(t_2 - t_1)}{L_1}\right]^{\frac{A+B}{B}}$$

It is believed that the success of this method of analysis in treating the theory of isotropic turbulence is an indication of its possibilities in treating other aspects of the turbulence problem.

Book Reviews

Seaplanes, by DANIEL J. BRIMM, JR.; Pitman Publishing Corporation, New York, 1937; 140 pages, ill., $2.50.

The gentle art of mystification seems to be absent from Mr. Brimm's book on seaplanes. It is a straightforward narrative of what a pilot or private owner of a seaplane would wish to know when he flies from the water. The book starts with a brief description and comparison of amphibians, float seaplanes, and flying boats and covers in a non-technical manner some of the engineering considerations which especially affect water-alighting aircraft. The requirements of a seaplane base and descriptions of various types of ramps, beaching dollies, and landing floats are enumerated and well illustrated. The special equipment necessary on seaplanes, such as anchors and mooring bridles are described and there are many suggestions as to useful equipment and handy gadgets. Corrosion proofing maintenance and repair work receive due attention.

Probably the best chapters in the book are those devoted to the handling of a seaplane under varying conditions of wind and water. These chapters would be of interest to land pilots and yachtsmen and are of real value to even the experienced seaplane pilot. Mr. Brimm's years of personal experience in water flying combined with his engineering knowledge enables him to explain the reason for maneuvering in a specified manner under given conditions of wind and water. The master seaplane pilot, like the master sailor knows a lot of little tricks which he uses when emergencies arise and the general account of how to handle a seaplane is interspersed with descriptions of the fine points which can make the handling of the seaplane an art.

The book is well illustrated and very readable so that it would be of interest to land-plane pilots. For those connected with water flying, whether they be pilots, owners, mechanics, or base operators the book will be of real value as it covers in a very practical and comprehensive way the many angles which are peculiar to seaplanes.

E. D. OSBORN
Edo Aircraft Corporation

Contact, by CHARLES CODMAN; Little, Brown and Company, Boston, 1937; 247 pages, $2.00.

If motion picture directors ever wish to justify some of the reckless and undisciplined characters which they give to wartime pilots, this book will give them much support.

The twenty years which have gone by since the events of the book occurred have had a dulling effect on the keenness of interest in diaries of aviation, particularly as there have been dozens published in many languages. But Mr. Codman has a staccato style of writing which does carry the reader along with a sustaining degree of attention.

He was a member of the famous squadron that was carried by a tail-wind into Germany and could not return. Fortunately, he was off duty that day and was a participant later in a famous "dog fight" and was the sole survivor of a squadron of six airplanes. By far the best part of the book is his description of his career as a prisoner in Germany and his "escape" with others after the armistice. The amusing part of this escapade was that the party was escorted politely to the Swiss border.

It is seldom that a book bears such internal evidence of the joy of writing that these pages give.

The M.I.T.-Sperry Apparatus for Measuring Vibration

C. S. DRAPER and G. P. BENTLEY, *Massachusetts Institute of Technology*
H. H. WILLIS, *Sperry Gyroscope Company*

Presented at the Engines and Fuels Session, Fifth Annual Meeting, I. Ae. S.
January 28, 1937

Summary

THE electrical vibration measuring apparatus developed by the Massachusetts Institute of Technology in cooperation with the Bureau of Aeronautics of the Navy is described with improvements introduced by the Sperry Gyroscope Company. This new equipment is adapted to recording linear and torsional vibration of airplane structures and power plants in flight. The system uses electro-magnetic pick-up units of small size which operate a compact photographic oscillograph through a special integrating amplifier. Two simultaneous records are taken from separate pick-up units so that phase and amplitude relations can be studied. Sample records are included and a simple analysis is outlined for a practical case.

Introduction

A remote recording system for measuring vibration was described at the 1936 Annual Meeting of the Institute by two of the present authors.[1] This apparatus was developed as a cooperative research between the Bureau of Aeronautics of the United States Navy and the Massachusetts Institute of Technology. The Sperry Gyroscope Company became interested in the project as manufacturing agent for certain apparatus items, and has since contributed a number of improvements and refinements. This paper will describe the apparatus in its latest form as used for flight testing and will show typical examples of vibration records.

General Installation

Fig. 1 shows an installation for measuring vibration in flight. Small pick-up units are mounted rigidly on the airplane or engine structure. Each unit transfers one component of vibration at a single station into electrical impulses. A typical pick-up mounting is indicated at A. Connections from each pick-up are brought to a distribution panel, B, and then to a selector panel, C. A tap switch on this panel makes it possible to connect any desired pair of pick-up units to the two-channel amplifier, D. The output of this amplifier is recorded photographically by the portable oscillograph, E.

[1] C. S. Draper and G. P. Bentley, *Measurement of Aircraft Vibration in Flight*, Journal of the Aeronautical Sciences, Vol. 3, No. 4, February, 1936.

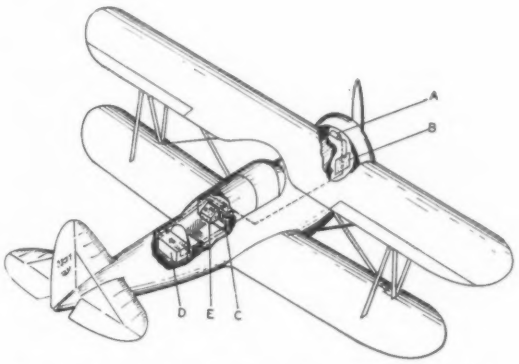


FIG. 1. Installation for measuring vibration in flight.

A number of improvements have extended the utility of the new apparatus as compared with the equipment already described.[2] The oscillograph has been modified to simplify and speed up operations. Simultaneous records from two pick-ups are taken by the use of two sensitive elements. With this arrangement, all components of linear and torsional vibration of a structural unit can be determined by records taken in pairs from a group of properly placed pick-ups. In addition to displacements, vibratory strains can be recorded directly by means of a recently developed pick-up which is actuated by relative motion between two points on a structural member. The existing equipment can thus be used to investigate all the quantities of interest in aircraft vibrations problems.

Pick-up Units

The pick-up units for measurement of vibration displacements are based on the familiar "seismographic principle." The seismic element is a mass carried by a supporting element which is rigidly connected to the vibrating member. For linear vibration measurements, the seismic element moves in one direction with respect to the vibrating member with a spring coupling and a damping element. The spring is made so weak that in the operating range the seismic element moves without vibration at the average speed of the vibrating member. Under this condition a record of relative motion between the supporting element and the seismic element will give the vibratory displacements it is

[2] *Loc. cit.*

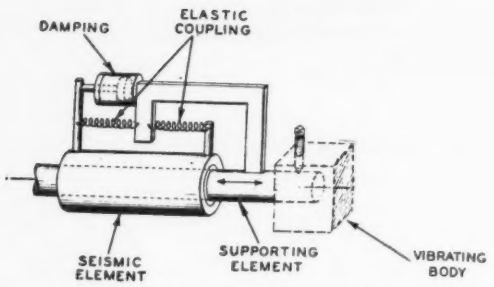


FIG. 2. Mechanical elements of linear vibration pick-up.

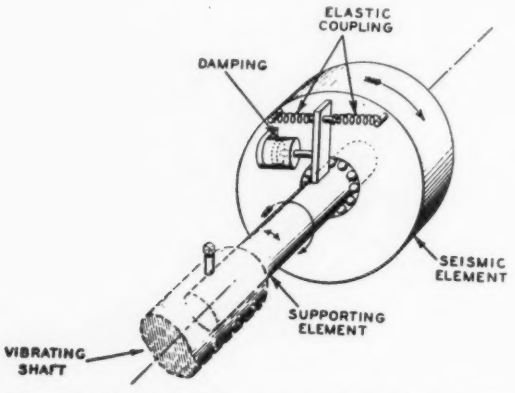


FIG. 3. Mechanical elements of torsional vibration pick-up.

desired to measure. Figs. 2 and 3 show the essential mechanical elements of pick-up units for linear vibration displacements and torsional displacements, respectively.

Figs. 4 and 5 show the application of the electro-magnetic generator principle to transform the mechanical displacements in a vibration pick-up unit into electrical impulses. In Fig. 4 the radial magnetic flux set up in an air gap by a permanent magnet is carried along a cylindrical winding by relative motion between the seismic element and the supporting element. This action induces a voltage in the coil which is proportional to the relative velocity. In Fig. 5 a motion in torsion between the seismic element and the supporting element causes a transfer of magnetic flux from one side to the other of the armature, which induces a voltage proportional to the relative velocity. This voltage is applied to stationary terminals by means of slip rings.

Fig. 6 shows a linear vibration pick-up unit at A with the bakelite cap, S, which serves to insulate the electrical terminals. The working parts of a unit assembled for horizontal operation are shown at B, while the coupling springs of the unit at C have been changed for vertical operation. This particular type of pick-up unit has a weight of slightly over one pound. Fig. 7 shows the external appearance of two other types of linear vibration pick-up units placed on either side of the unit of Fig. 6. The largest unit is particularly

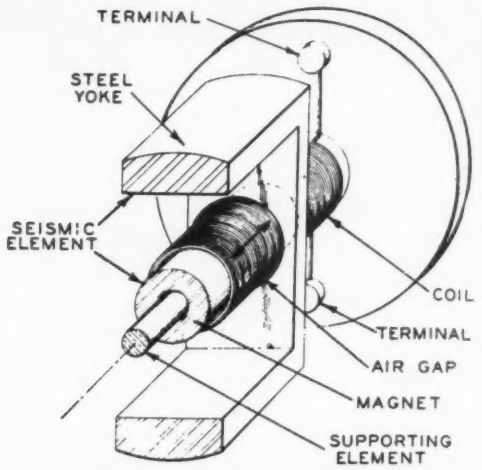


FIG. 4. Electro-magnetic generator for linear vibration pick-up units.

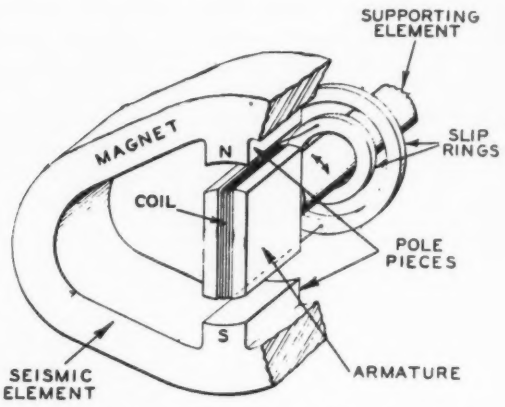


FIG. 5. Electro-magnetic generator for torsional vibration pick-up units.

adapted to the measurement of small amplitude vibrations with frequencies as low as two cycles per second. The smallest unit has a weight of less than four ounces and a range of operation which includes the vibrations encountered in airplane problems. All of the linear units have oil damping which can be controlled by changing the oil viscosity or by adjustment of orifices.

The external appearance of the torsional vibration pick-up unit is shown at the left of Fig. 8 and the parts of a disassembled unit at the right. The seismic element is a brass cylinder, A, which carries the magnets, B, and the pole pieces, C. The steel flange, D, is designed to be rigidly connected to the shaft whose vibration is being recorded. The supporting element, E, is clamped to the flange by the nut, F, and carries the armature, N, which fits between the pole pieces, C, when the unit is assembled. The coupling springs are connected between pins on the rear faces of the seismic element and the mounting flange. The slip rings are set into the bakelite disc on the supporting element and make contact with the terminals, R, through

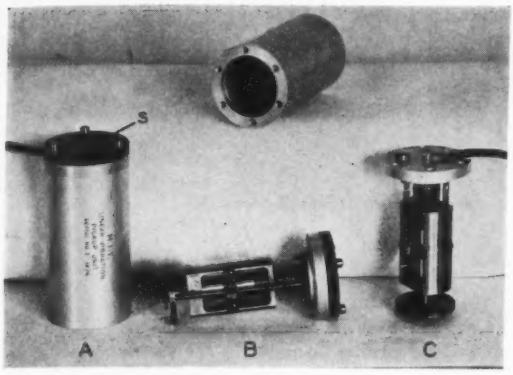


FIG. 6. Linear vibration pick-up assembly.

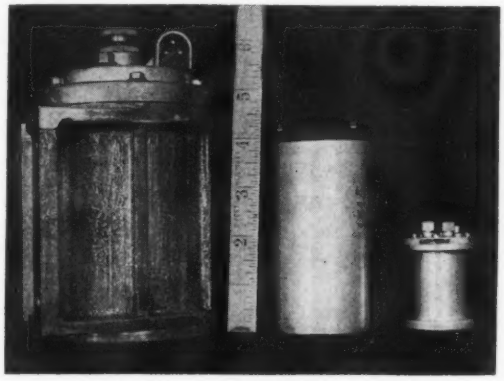


FIG. 7. Linear vibration pick-ups.

small carbons brushes. The aluminum cylinder, Q, carries the terminals which are connected to a flexible double conductor cable clamped under the bakelite cap, U. The unit has a weight of about three and one-quarter pounds. Damping is supplied by a spring-loaded bakelite plug which introduces friction between the seismic element and the mounting flange.

The pick-up unit for strains is an instrument for transforming small motions into voltage changes proportional to the velocity of motion. Fig. 9 shows the essential parts of the strain pick-up, which incorporates suggestions due to W. M. Bleakney of the Bureau of Standards. A magnet, A, and yoke, B, maintain flux in cylindrical iron armatures, C, which carry coils of fine wire, D. These coils are connected in series to the terminals, E. The armatures are freely suspended in the gaps by means of thin diaphragms, F. The armature unit is clamped to the member under test through knife edge, G, at one end of the gage length, while a point on the yoke is clamped at the other end of the gage length by the knife edge, H. Any strain in the member which is accompanied by a displacement between the knife edges will cause a shift in flux from one side to the other of each armature and produces a voltage in the coils proportional to the rate of displacement. The strain pick-up has a weight between two and three ounces depending on the gage length chosen.

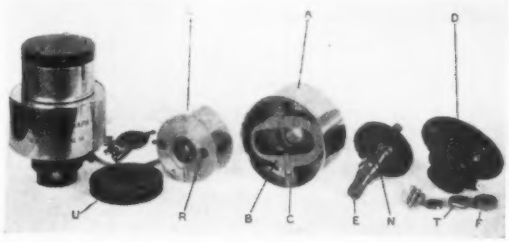


FIG. 8. Torsional vibration pick-up.

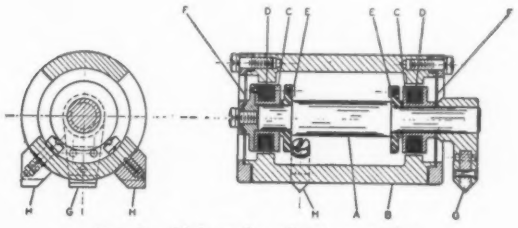


FIG. 9. Pick-up for vibratory strains.

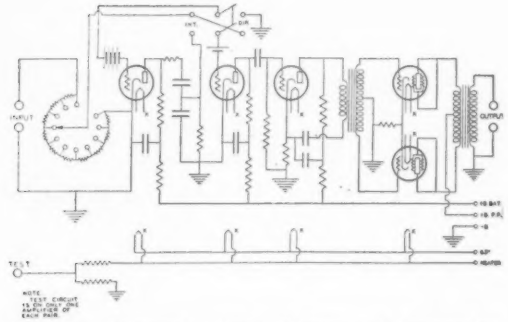


FIG. 10. Schematic circuit diagram of integrating amplifier.

When used with the standard amplifier and oscillograph, displacements on a specimen are magnified about one thousand times.

AMPLIFIERS

Special amplifiers are used as coupling elements between the pick-up units and the oscillograph for producing a photographic record of vibration displacements. Fig. 10 is a wiring diagram of the amplifier which is a conventional design except for the "integrating circuit" used between the first and second stages. In this arrangement a resistance in series with two condensers is connected across the first tube load resistor. The elements are so chosen that the current in this circuit is proportional to the applied alternating voltage over the operating range of frequencies. Under this condition the voltage across each condenser will be proportional to the time integral of the a.c. voltage across the first tube resistor. This integrated voltage is applied to the grid of the second tube by a connection between the two condensers. This arrangement serves to isolate the grid from the first tube plate voltage. The double-pole double-throw switch removes the

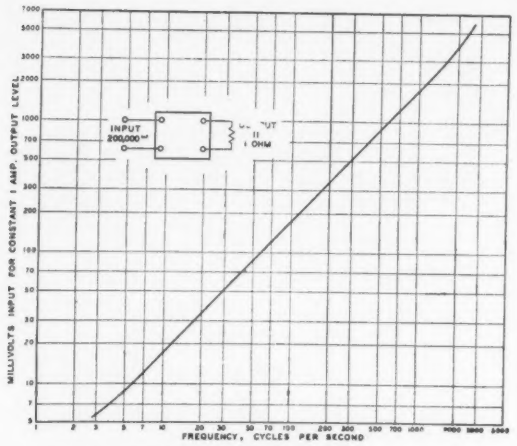


FIG. 11. Sensitivity curve for integrating amplifier.

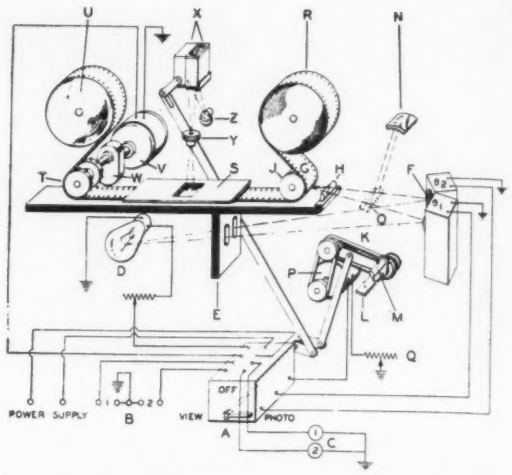


FIG. 12. Schematic diagram of recording oscillograph.

integrating circuit when it is desired to use the unit as a straight amplifier. The output transformer is designed to connect directly into an electro-magnetic-oscillograph of about one ohm resistance.

Fig. 11 shows the sensitivity curve for the integrating amplifier. The input voltage required to give a fixed output increases directly with frequency from about five cycles per second to fifteen hundred cycles per second. Since the output of an electro-magnetic generator type of vibration pick-up unit increases directly with frequency for a fixed amplitude of vibration, the combination of such a pick-up unit with an integrating amplifier will give the desired result as an output which is independent of frequency for a constant amplitude. The latest unit contains two independent amplifiers connected to a common power supply. This unit weighs about 80 lbs. and is 18 inches high, 9 inches wide, and 11 inches long.

OSCILLOGRAPH

Fig. 12 is a schematic diagram of the recording oscillograph. The instrument is designed to be operated by a single control lever, A, which connects the two independent sets of input terminals, B, to the meters, C, when in the OFF position. When the control lever is turned to the PHOTO position, the ribbon filament lamp, D, is lighted and the oscillograph elements, 1 and 2, are connected to the terminals, B. Light from D passes through openings in the light baffle, E, and is reflected from mirrors, F, in the elements 1 and 2. The light beams are focussed to a spot on the film, G, over the roller, J, by means of the cylindrical lens, H. When it is desired to examine the vibration visually, the lever, A, is moved to the VIEW position which raises the unit, K, until the mirror, L, intercepts the light beams as shown in the dotted position at O. The motor, P, whose speed can be adjusted by means of the rheostat, Q, rotates mirror, L, about its long axis. At the same time the cylindrical lens, M, mounted parallel to the mirror is revolved so that it focusses the beams as they are swept across the screen, N. The supply of film is in the form of a standard roll of motion picture stock shown at R. From the roller, J, the film is carried under a masking gate, S, over a sprocket, T, and onto the take-up reel, U. The sprocket is driven by a motor, V, through a change-gear box, W. This motor is started when the control lever is moved to the PHOTO position. The movement of the control lever to make a record automatically advances the two counters, X, by one number. After a record is completed, the number is photographed on the film by means of the small lamp, Z, and the lens, Y.

The recording oscillograph can be operated on either alternating or direct current. The only adjustment necessary is to shift a switch to the properly marked side. No auxiliary means for timing the records is required since the film-drive motor is governor-controlled to have a constant speed. The instrument can be loaded in daylight and the take-up reel can be removed in daylight.

Fig. 13 is a photograph of the recording oscillograph with connections made for use. Either a.c. or d.c. power at 12 volts is supplied through the cable, H. The a.c.-d.c. selector switch is shown at D. The other controls can be identified by labels on the instrument itself. The recording oscillograph has a weight of 38 lbs., is 14 inches long, 10 inches wide, and the greatest height is 8 inches.

CALIBRATOR

Over-all calibrations of the equipment are carried out by means of the unit shown in Fig. 14. A heavy flywheel, A, is driven at constant speed from a synchronous motor, B. The speed can be adjusted by means of a variable speed transmission, C. To calibrate a linear vibration pick-up, the unit is mounted on an eccentric-driven follower, as shown at D. The frequency of vibration is equal to the speed of the flywheel. A double-eccentric arrangement makes it

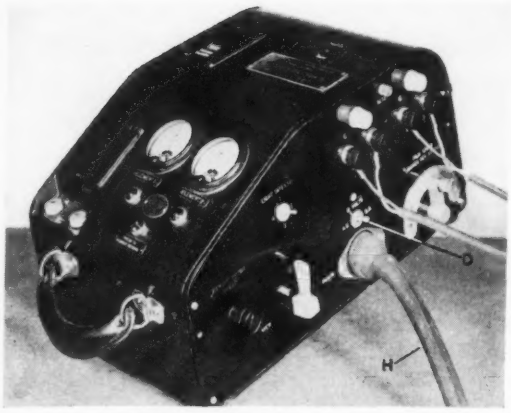


FIG. 13. Control panel of recording oscillograph.

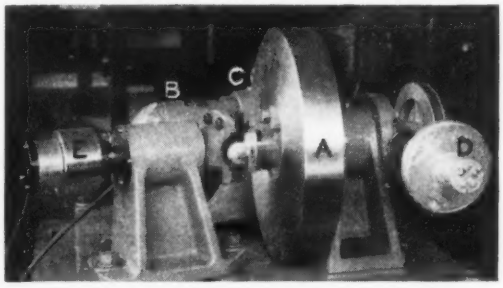
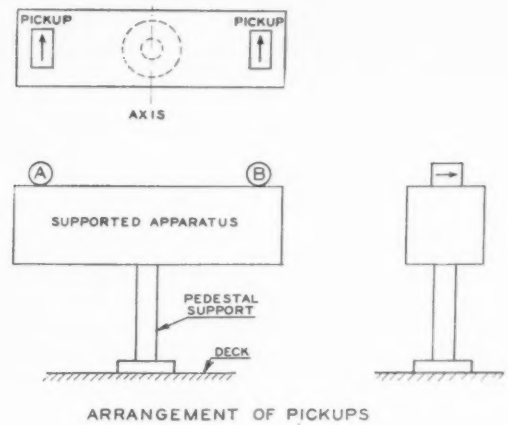


FIG. 14. Calibrator for vibration pick-ups.



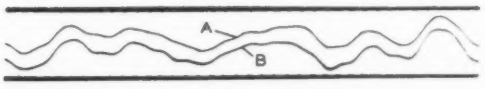


FIG. 15. Determination of linear and torsional vibration components by means of linear vibration pick-ups.

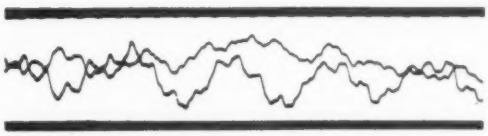


FIG. 16. Linear vibration records taken in flight.

possible to adjust the amplitude of motion from zero to 0.050 inch. Torsional vibration of known amplitude is obtained by means of a well-made universal joint with the driven shaft set at a small angle with the driving shaft. The vibration will be a pure sine wave for practical purposes if the shaft angle is not greater than ten degrees. A torsional vibration pick-up unit mounted for calibration is shown at E. The calibrator has a range of zero to 100 cycles per second in linear vibration and twice this range in torsional vibration since two cycles are completed for each revolution of the shaft.

SAMPLE RECORDS

Fig. 15 shows a simple example of two linear pick-ups to study vibration in an apparatus attached to the deck of a marine vessel. The essential features of the problem are shown in the diagram with the pick-ups located to determine both linear vibration in the direction of the arrows and rotation about the support. The records labeled (A) and (B) were taken from the corresponding pick-ups. Since the displacements at the two units were in phase and of the same amplitude, the vibration must have been non-rotational.

The records of Fig. 16 were taken in flight with linear pick-ups attached to a structural member in the nose of a bimotored airplane. The upper record shows the vertical motion, while the lower trace shows the cross-ship vibration at the same point. The high-frequency component on the lower record is due to the propeller blades passing close to the structure; the lower frequency is due to torsional vibration of the fuselage.

DISCUSSION

Vibration troubles have been especially severe in high-performance airplanes. Efforts to remedy these difficulties have been handicapped by the absence of quantitative information on the vibration itself. The proper steps to eliminate harmful effects in a member often become obvious when an experimental analysis is available with resonance curves for each component of vibration. To be sure that no essential factor has been neglected in such a complicated system as the airplane, data must be taken in actual flight. The new apparatus seems to meet this need for a practical means of making precise measurements on airplane vibration.

Although the equipment has been in use by the Bureau of Aeronautics and certain manufacturers but a short time, much valuable information has already been collected. These data are now being analyzed to determine the proper design changes to eliminate objectional vibration in aircraft structures and power plants.

Reduced Maintenance of Aircraft Engine Power Plants

A. V. WILLGOOS, *Pratt & Whitney Aircraft, Division of United Aircraft Corporation*

Presented at the Engines and Fuels Session, Fifth Annual Meeting, I. Ae. S.
January 28, 1937

PERHAPS in every case of fleet-operated transportation equipment, the expense of engine upkeep represents a sizable proportion of the total cost of operation. This is certainly true in aviation, where maintenance expense during the life of the engine may possibly equal the original selling price of the engine. Total maintenance cost is, of course, a very comprehensive item including such tangible expenses as direct labor costs, parts replacement cost, testing costs, outlay for overhaul machinery, and interest on capital invested in spare parts. In addition are the indirect or intangible items of expense which include field maintenance required for frequent periodic engine inspection and adjustment, revenue loss incurred during engine changes, whether at the maintenance depot or at remote stations, and the loss of prestige caused by delay to passenger, mail, and express service, in the event of engine failure away from the overhaul depot.

All of these expense items are affected by two factors; namely, engine reliability and engine durability. Both factors in turn are affected by engine design, operating technique, power output, the use of proper oil, fuel, and overhaul technique. Power output is quite definitely limited by the rating of the engine for the particular job to be done, and the engine is proof-tested by its manufacturer to substantiate this rating. The operator, in turn, seldom departs from the recommended fuels and oils, in order to assure satisfactory service when operating the engine at its proof-tested rating. It may also be granted that overhaul practice is well established and that maintenance trouble from this source can quickly be detected and corrected. The variables in maintenance problems are then confined to engine design and to operating technique.

Improvement in design over the past ten years is forcibly reflected in the increase in power ratings per cubic inch cylinder displacement. It is not uncommon to find 1936 engine ratings 100 percent greater than 1926 ratings for engines of the same displacement. It is of particular interest that even greater dependability and durability have been obtained with the newer ratings as compared with the old ratings, and this has accomplished a tremendous decrease in maintenance costs. This is significantly substantiated by the fact that most of the major airlines have found it possible to confine all overhaul and practically all maintenance to one depot, and have been able to close their additional shops which were situated at strategic points over the entire system.

Studying the improvements made in the engines to substantiate the higher power ratings will quite obviously indicate the reason why maintenance costs have been lowered. To enable the engine to develop greater power, the strength of most of the parts had to be increased considerably. In addition, it was found necessary to improve the oiling system to assure suitable lubrication to all parts. An automatic oiling system was, therefore, devised to replace grease lubrication and the results were so satisfactory that it was immediately found possible to obviate periodic inspection of a number of vital parts between overhaul periods. This particularly applies to the valve gear which, in the days of grease lubrication of these parts, required removal of the separate cylinder covers to inspect and adjust the valve mechanism as well as to insure adding an adequate supply of grease at least every five hours. Likewise, it was necessary at these periods to uncover and thoroughly inspect push rods to insure that they were being lubricated. With the new lubrication system, however, one major airline now finds it possible to run their engines 600 hours between overhauls without inspection of any parts other than spark plugs at 60 hour intervals and change of oil at around 120 hours.

It is perhaps even more remarkable that cost for replacement of parts has actuallly decreased during this period of advancement of operating time between overhauls. Again this reflects upon the improvement in design as well as upon the effect of the application of automatic devices. For instance, considerable attention had to be paid to the redesign of exhaust valves to obtain the high increase in power rating along with a demanded decrease in fuel consumption, both of which ordinarily affect valve life adversely. The application of automatic oiling to the valve gear probably contributed as much as the improvement in design to the increase in valve life. Exhaust valves of the old design and lubricated only by grease were considered safe for a period of around 900 hours. The new design with automatic oiling shows no distress and practically no wear for operating periods up to 2500 hours.

It is significant that the redesign of the Wasp engine practically cut parts replacement cost in half and at the same time permitted double the length of time of operation between overhauls. In one instance, taking the overhaul figures of fifty representative engines operating 500 hours between overhauls, the cost of the S1H1-G Wasp averaged $75 per engine. This was for a geared engine. The average for the direct drive engines of an older model when operated at the

same power, was about four times this, even though the period between overhauls was confined to 300 hours.

The decrease in line maintenance is naturally a function of dependability of the component parts of the engine. The time of operation between inspection periods is naturally limited to the interval which will assure trouble free operation. Engine dependability without trouble is also a function of the manner in which the engine is operated. It is generally recognized that the technique of engine operation as followed by flying personnel in different airlines, in different localities with wide variations in atmospheric conditions and in the various types of military and commercial operations, plays a most important part in the problem of engine maintenance. It can be understood then that the adoption of automatic devices which relieve the pilot from paying constant attention to power output, mixture strength, and engine speed, has in turn contributed greatly to the improvement in dependability and thereby the decreased maintenance. United Aircraft Corporation has been most active in the development of such automatic devices, and the application of these devices along with the other improvements in general design has practically coincided with the remarkable improvement in engine durability, which has permitted the 100 percent increase in operating time between overhauls.

Cylinder wear has been a function of piston design, cylinder barrel material, mixture strength, and power output. New designs of pistons along with the use of harder materials and tapered cylinder barrels undoubtedly have contributed greatly to the elimination of cylinder wear. Yet, there is no question but that the use of the automatic mixture control, which definitely holds the mixture strength as low as it is safe to operate, has contributed its part to the almost total elimination of cylinder wear in the newer engines. Of fundamental importance is the fact that engine operation when automatic devices are used is practically confined to the conditions under which the engine is proof-tested during the design stages at the factory. The maintenance figures of airlines which have applied these automatic devices speak for themselves and show the value of comprehensive development not only of the engine itself but of devices which assure proper and safe operation.

The important maintenance problems which still exist are now confined to the periodic inspection of spark plugs, to permissible operating time between oil changes and possibly to the continued improvement of those parts in the engine which are now subject to wear and to replacement at time of overhaul. Considerable attention is being paid to the improvement of spark plugs with the hopeful expectancy of being able to eliminate their replacement during the permissible operating time between overhauls. Likewise, some attention is being given to increasing the time between oil changes. This may possibly be accomplished by the use of centrifugal oil cleaners, which may be expected to collect sludge and thereby obviate the necessity for oil drainage. This would naturally decrease line maintenance. Overhaul maintenance costs will continue to be decreased as the operating time between overhauls is lengthened, particularly as it is general practice to replace rings, gaskets, a small number of bearings, and accessory gears at each overhaul period. It can be assumed, therefore, that this cost can only be reduced by improving the design of these parts so that they will operate satisfactorily for a longer time.

Many of these parts as now manufactured would operate satisfactorily for at least twice the length of time between overhauls. The life of some parts, for example, piston rings, is affected by the normal teardown, inspection, and cleaning operations. In such cases it is thought to be economy to replace them as a routine matter at time of each overhaul, rather than risk delays in operations due to malfunctioning of such parts.

With these accomplishments, it can be seen that the real value of an engine does not lie only in its original cost. An engine capable of running long periods between overhauls without attention, and which costs but little to keep in good condition, may rightfully be a more expensive engine in sales price. In determining its true cost, however, full consideration should be given to the tangible and intangible maintenance expenses, and to the added prestige and psychological advantages to be gained from trouble-free operation.

The Use of the Trim-Angle Indicator for Seaplane Take-Off

MELVIN N. GOUGH, *National Advisory Committee for Aeronautics*

Presented at the Flying Properties and Flight Testing Session, Fifth Annual Meeting, I. Ae. S. January 29, 1937

THE importance of the whole subject of best trim angles is considerably increased when seaplanes of high-power loading are considered. The take-off characteristics of seaplanes that incorporate the results of recent research in hydrodynamics differ markedly from those of earlier machines. The testing of models of hulls in the N.A.C.A. tank has provided data from which it is possible to determine, for any hull tested, the angle of trim that gives minimum resistance to propulsion at each speed and load condition from rest to take-off. The angle of trim is the angle assumed by the float or hull with the horizontal surface of the water. The reference line generally used to define this angle is the keel just forward of the main step.

The past few years have also seen the introduction of methods of construction and of devices that materially increase the lift of wings and the available thrust, especially at low speeds, and that increase the control of attitude by the pilot. The pilot, therefore, now has it within his power to predict and control the events of take-off of a seaplane very nearly as he desires and, consequently, to cause the take-off to take place in the optimum time and distance considering the conditions existing.

It is the purpose of these notes to make clear to the pilot how, with the aid of an N.A.C.A. trim-angle indicator, to obtain the optimum take-off characteristics of seaplanes and flying boats of modern design.

The necessity of running a seaplane near the best trim angles during a take-off is generally recognized, but complete data on the effect of deviations from the best angle have not been available until recently. The knowledge of the hydrodynamic properties of floats and hulls is obtained mainly from tests made by the towing of scale models in a tank. A general test, as made in the N.A.C.A. tank, shows the performance of the model at all water speeds, waterborne loads, and attitudes. Attempts are also continually being made to improve the aerodynamic shape and at the same time to improve the hydrodynamic properties of low resistance, good stability, freedom from porpoising, and freedom from spray. Small changes in form and dimensions are found to produce large effects on all these characteristics. Much remains to be done to verify the results in full scale, however, and it is believed that some form of the trim-angle indicator will play a large part in the determination and practical application of the results.

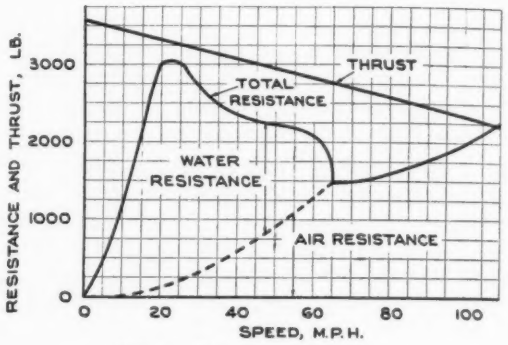


FIG. 1. Resistance of seaplane.

Consider the resistance to motion of a particular seaplane, shown in Fig. 1. The solid curve represents the minimum resistance obtained up to the high-speed condition of the seaplane. The resistance encountered up to the time that take-off occurs is subdivided into that due to water and that due to air. It will be noted that the hydrodynamic resistance forms a major portion of the total. The point of maximum resistance just before the craft changes from "plowing" to "planing" is termed the "hump" and occurs at the low water speed as shown. In older models there is usually no greater resistance, but in some of the newer designs a still greater resistance, or high-speed hump, may appear near getaway speed. The point at which the airplane leaves the water is called the "point of getaway" and occurs at a speed equal to, but usually slightly greater than, the power-on stalling speed. A thrust curve is shown so that an idea may be gained of the excess thrust available for acceleration, at any speed. It is apparent that the quickest take-off will occur when the total resistance on the water is a minimum and when there is a maximum mean net thrust for acceleration, and further provided there is no one speed at which the resistance is greater than the thrust available.

The difficulty, encountered in model tests of simulating the variation in the wing lift with the trim and hence the manner in which the load on the water changes, has made it more convenient to conduct the model tests for a definite series of speeds, loads, and trim angles. Typical data obtained from such tests are shown in Fig. 2. The resistance obtained at each of three speeds is plotted against trim angle for various load conditions. All the curves show the same general trend. A deviation of more than 1° from the best trim angle results in an appreciable increase in water

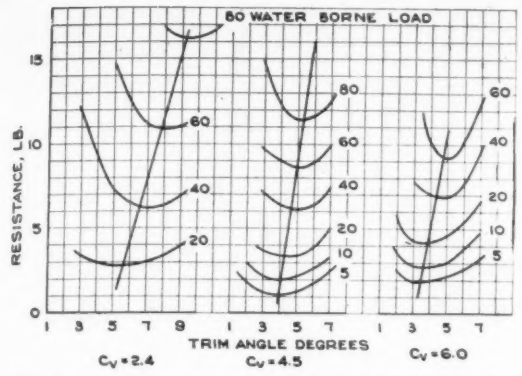


FIG. 2. Variation of model resistance with trim angle.

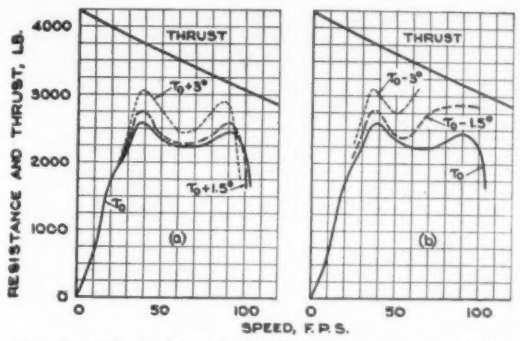


FIG. 3. Effect of positive and negative changes of trim angle.

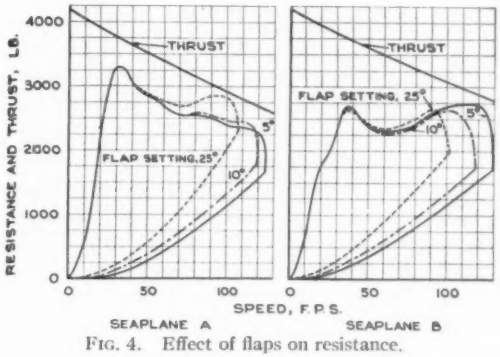


FIG. 4. Effect of flaps on resistance.

resistance over the minimum value; and the trim angle at which the resistance is a minimum becomes larger as the loading is increased. These curves establish the fact that there is a definite trim angle giving the least water resistance for each speed and load.

Applying such data to a particular example, curves of total resistance encountered during a take-off run may be obtained to show quantitatively the effects of deviations above and below the best trim angle. (See Fig. 3.) The marked increase in resistance at the hump speeds should be particularly noted. The effect of pulling the seaplane up to high attitudes to decrease the getaway speed and thus the length of the take-off run can be seen in Fig. 3(a). If the pull-up is started before the stalling speed is reached, the increase in total resistance may more than offset the advantage obtained. The very disastrous effects of too low an angle at the higher speeds is shown in Fig. 3(b). The undesirability of rocking, or pitching due to porpoising, is evident from both figures. If a serious loss in net accelerating force is to be avoided, the trim should be held within about 1° of the best angle until at least the stalling speed is reached, at which time the airplane should be taken off as quickly as possible by applying a positive moment with the elevators. It follows that, owing to an increase in loading, a decrease in thrust, and most particularly an incorrect trim, the relation between resistance and thrust at either of the hump speeds may be such that acceleration beyond those points, and thus take-off, is impossible.

Mention should be made that all the data obtained from model tests are based on water speeds under dead-calm conditions. Neglecting for the present the effect of water-surface conditions met in practice, it has been found that the best trim angle recommended for a given water speed during a take-off in a dead calm also gives practically the best results for take-off into a wind.

The effect of high-lift devices on take-off deserves some brief discussion in connection with the subject of trim angle and take-off. Fig. 4 shows the effects of flaps on resistance during take-off of two seaplanes. In both cases there is a marked increase in air resistance and reduction of getaway speed caused by lowering the flaps. In the case of seaplane A, where the water resistance is but little affected, the increase in total resistance beyond the first hump causes a large reduction in the net accelerating force, and take-off may even be impossible unless close attention is paid to maintaining the best trim angle so that the high-speed hump may by passed ideally as shown. In the original design of seaplane B, the wing setting was reduced to secure a more favorable attitude of the hull in flight. The getaway speed is excessively high as a result of the lower angle of attack at which the wing must operate to keep the hull at its best trim angle. Here lowering the flaps reduces the water-borne load and thus resistance and improves the take-off. Suffice it to say that because of the large number of variables involved, the desirability of incorporating or using high-lift devices in a seaplane as an aid to take-off must be determined individually for the arrangement under consideration. Undoubtedly, it will depend upon the net accelerating force available. However, in all computations or proof tests the determination and maintenance of the best trim angle of the hull is essential. In fact, the variation in total resistance due to the flap changes shown is no greater than that previously shown due to small changes in trim angle.

Fig. 5 shows the manner in which the best trim angle varies with speed for a particular seaplane and load

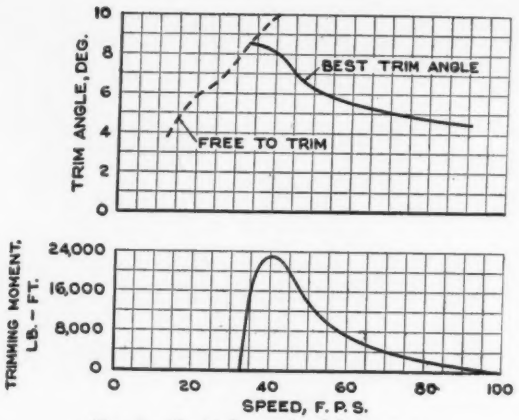


FIG. 5. Best trim angle and moment.

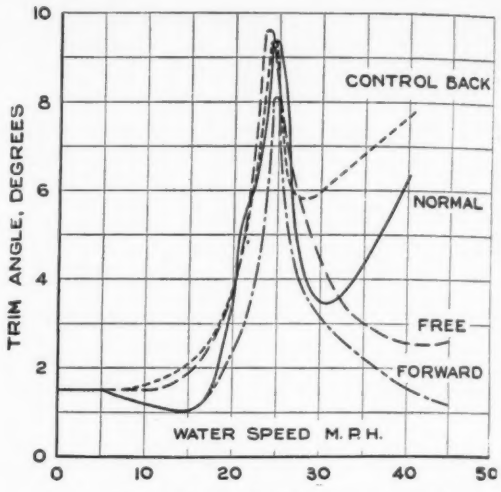


FIG. 6. Effect of control position on trim angle.

condition as obtained from the general tank test data for the hull used. On the upper half of the figure it is seen that at the lower speeds little or nothing need be done by the pilot because the attitude assumed by the hull when left free to trim is usually as good as can by otherwise obtained. Further, as will be explained later, not much can be done about it. But just before the speed for the first hump is reached the best trim angle departs rapidly from the free-to-trim attitude which would exist from there on. The lower curve shows the moment that must be produced to overcome the natural tendency of the hull to assume its free-to-trim attitude for the remainder of the water-speed range.

The limits of the range of trim angles that can be influenced by the pilot is controlled by the design of the tail, the moment produced by the thrust, and by the hull itself. It follows that a seaplane should be provided with large horizontal control surfaces and well-balanced elevators. In general, however, poor control exists at the very low speeds. In Fig. 6 is shown an example of the effect of control position on trim angle for a large flying boat of early design. Little change in attitude could be produced until after the hump speed was passed. This probably accounts for the rocking that was resorted to in order to "get-on-the-step." Actually, the reduction of resistance beyond the hump is due to the transition from the plowing stage at the lower speeds to the planing stage at the higher speeds. Getting-on-the-step is accomplished merely by obtaining the speed required for it. Rocking, by its dynamic effects in pitching, apparently allowed a greater range of trim angles to be passed through in the hopes that when that for minimum hump resistance was encountered the excess thrust, which in those days was mighty little at best, would accelerate the boat into the higher speed planing range. Fortunately, the control at low speeds has been vastly improved in modern designs and it is possible for the pilot to take charge considerably earlier than is indicated in this figure. In a well-designed seaplane, best results will be obtained when the controls are used to dampen pitch rather than to produce it. When rocking must be used to get clear of the water at take-off speed, it is usually indicative of poor design of the afterbody of the hull.

It may be possible for an experienced seaplane pilot to obtain good take-off performance with a given machine by determining the trim angle from the "feel" of the acceleration. It is fairly well established, however, that the best performance thus obtained is considerably inferior to that resulting when the best trim angles calculated from test data are held throughout the run. The acceleration on which the pilot has to base his estimates is usually small. Further, the best trim angle is variable throughout the take-off run and the procedure of determining the correct trim at each speed becomes laborious as well as open to possible errors in the pilot's judgment. Even with a trim-angle indicator practical considerations would prevent the pilot from devoting his entire attention to it or adhering strictly to the recommended trim-angle curve.

Bubble-type or U-tube inclinometers, which have been installed in many seaplanes, are practically useless as trim-angle indicators owing to the effect of acceleration on them. It is hoped that at some future time a gyroscopic instrument will be available. A simple optical indicator, using the natural horizon as a reference, was suggested by James M. Shoemaker, one of the members of the Hydrodynamics Division of the National Advisory Committee for Aeronautics, and has been used on many seaplanes with remarkably good results. A diagram of this instrument is shown in Fig. 7. A lens projects the image of the horizon through a system of mirrors onto a ground glass screen graduated in degrees. Angular adjustment of the upper mirror permits zero setting. The screen is shielded from stray light as much as possible by a small flared hood. The image of the horizon is inverted but moves in the same direction as the bow and the keel of the

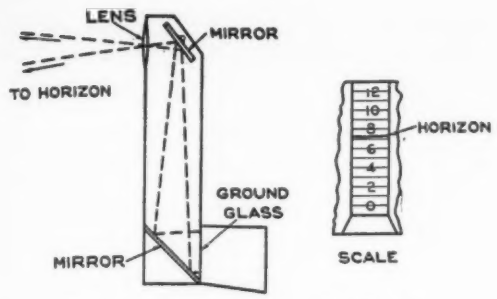


FIG. 7. Diagram of trim-angle indicator.

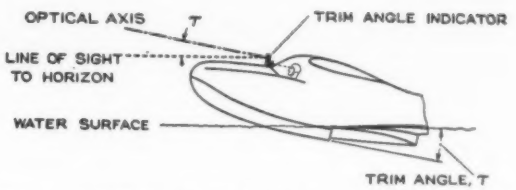


FIG. 8. Installation of a trim-angle indicator on a flying boat.

seaplane on which it is mounted. The position of the pilot's eye does not affect the readings. The 1° intervals on the scale are sufficiently large to permit reading to $\frac{1}{2}$° when the indicator is placed at the same distance as the other aircraft instruments on the dashboard. Many other possible forms for such an instrument can be called to mind. The type shown has served its general purpose very well. It has permitted viewing the horizon over the bow at high angles on all airplanes tried thus far, although its over-all height is but 9 inches. It is shown installed on a flying boat in Fig. 8. Mounted ahead, but to one side so as not to obscure the forward view, the screen is approximately at the same distance from the pilot, and directly above, the air-speed indicator. After installation, the horizon is positioned on the screen to indicate the keel angle directly.

The use of the indicator has required but little diversion of the pilot's attention. After but one or two attempts the many pilots who have tried it have experienced no difficulty in following both it and the air-speed meter without looking directly at them. The image of the horizon, which is usually just a dark line, has been discernible under a wide range of daylight conditions, including very dark days with a light mist and rain. Under such conditions, even with a dead-calm surface, there has always existed a horizon visible from a position a few feet above the water, even though it is lost immediately after take-off. Any distant object such as a boat, or at night a light, can be used as a reference.

So far it has proved necessary for the pilot to keep but two angles and one speed in mind during a take-off. These are the angles at the first hump and for planing, and the air speed necessary before lift-off can be executed. Following through the sequence of events during a take-off the nose is allowed to rise with the controls neutral as speed is gained until the angle is reached at which the hump should be passed. Every bit of forward control necessary is then used to maintain that attitude until the speed has increased beyond the hump speed. The free-to-trim tendency of the hull will then become more and more nose down. This tendency is encouraged until the trim-angle required in the high-speed planing range, or at the second hump, is obtained. The sink in the resistance curves, Fig. 3, indicates the relatively small necessity of maintaining the exact trim between the hump speeds. Toward the end of the planing run a rearward control force must be applied to overcome the natural free trimming tendency to nose down. The attitude is held until the air speed for lift-off has been reached.

Observation of the trim-angle indicator during take-offs performed in a normal manner by pilots without reference to it have revealed several incorrect general tendencies. The first hump is usually passed at too high an angle, planing is done at too low an angle, and there exists a general willingness to give in to false signs of possible lift-off rather than to consult the air-speed meter.

It is surprising what little practice has been required for a pilot to maintain a trim angle within $\pm\frac{1}{2}$° of that desired. Tendencies to porpoise are very effectively damped, in fact not allowed to develop, when first checked at the small angles which are detected by the indicator.

It bears repeating that the importance of the whole subject of best trim angles is considerably reduced when a seaplane of low power loading is considered. Little improvement could be expected in take-off of an airplane which normally gets off in 10 to 15 seconds. The heavily loaded flying boat with its high take-off speed and 40 to 60 seconds or more take-off time is the one to which the application of a trim-angle indicator will be most productive. The possibility of consistently obtaining the optimum take-off makes it particularly attractive to say nothing of the resulting uniformity of piloting technique.

Even though the characteristics of a particular machine are not known from model tests, it is possible to conduct a simple series of tests noting the time for take-off, wind, water, power, flap, landing conditions, and trim-angle variations and thus establishing the optimum conditions that can be reproduced at any time.

The development of a trim-angle indicator in which the water speed will be used to indicate the proper and corresponding trim angle to be obtained and held by the pilot has been suggested. There exists no reason to believe such an instrument would be too complicated to be of practical use to the pilot in greatly improving operations.

Visualization of Airflow by Means of Concentrated Beams of Light

JOHN D. AKERMAN, *University of Minnesota*

Presented at the Fluid Mechanics Session, Fifth Annual Meeting, I. Ae. S.
January 27, 1937

WHEN sunlight is admitted through a narrow opening in a darkened room, the dust particles flying in the air and crossing the beam become visible. This phenomenon reproduced in the wind tunnel may be utilized to visualize airflow around an object.[1]

Fig. 1 shows a sketch of the arrangement used. In the two opposite sides of a darkened wind tunnel are narrow slots through which parallel beams of light are thrown on the airfoil. Aluminum dust is introduced in the airflow by means of a blower at the opening of the wind tunnel. The camera is mounted on the top of the wind tunnel. A very small amount of light and aluminum powder is necessary to make the flow visible to the naked eye, but for photography a strong light is necessary.

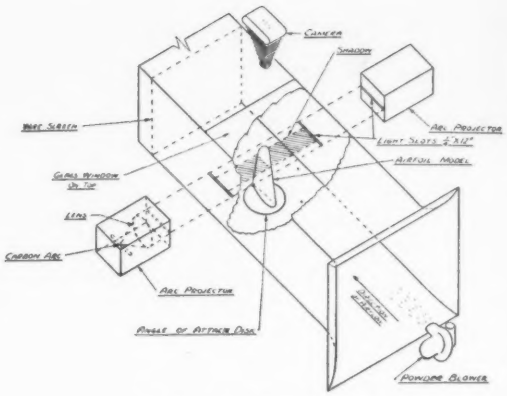
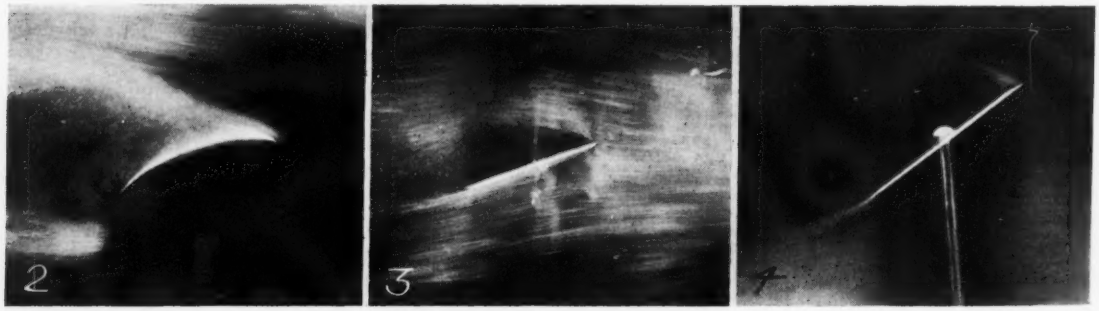
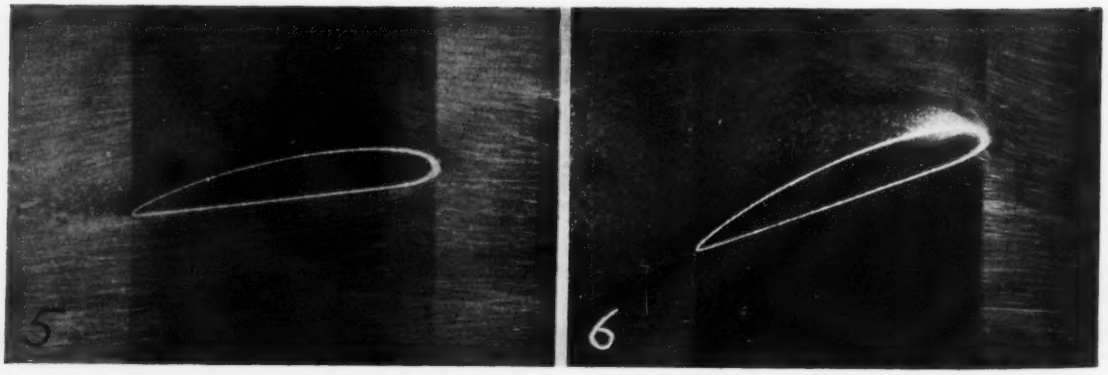


FIG. 1. Wind-tunnel set-up.

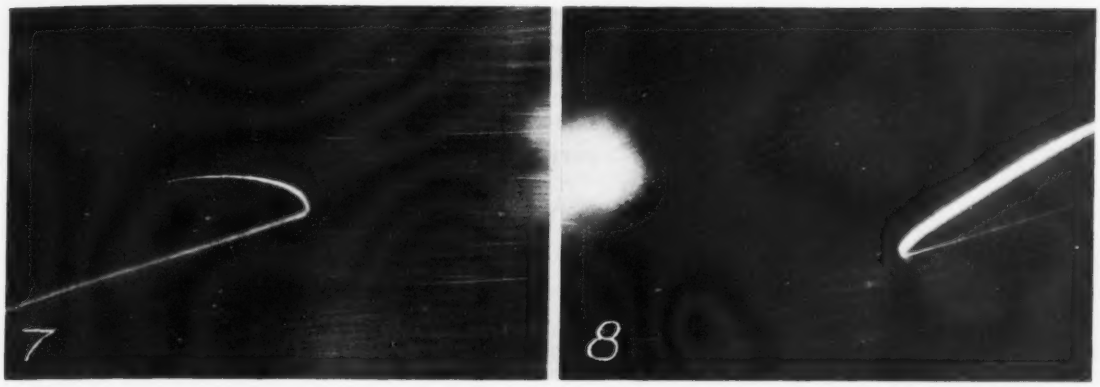
[1] This principle was first brought to the writer's attention by F. W. Pawlowski of the University of Michigan in 1925. The writer suggested the application of this principle to visualization of airflow around an airship model at the Guggenheim Airship Institute Dedication meeting in 1932.



FIGS. 2, 3, and 4.



FIGS. 5 and 6. Fig. 5—Wind velocity, 35 m.p.h.; angle of attack, 4°; time exposure, 1 second. Fig. 6.—Wind velocity, 35 m.p.h.; angle of attack, 18°; time exposure, 1/2 second. Note cross currents present in Fig. 5. are eliminated in Fig. 6.



FIGS. 7 and 8. Wind velocity, 50 m.p.h.; angle of attack, 18°; time exposure, 1 second.

Fig. 2 shows the airflow with light thrown from one side. The light is produced by means of four ordinary photographic magnesium flash bulbs with the camera left open in the dark. Therefore, the exposure time was equal to the length of the flash—four bulbs being ignited with the same current. This method produces very good pictures of the flow on one side, but shows a bad shadow on the other.

Fig. 3 was obtained by using flash bulbs on both sides of the object.

Since the use of flash bulbs was prohibitive due to their expense, a set-up as shown on Fig. 1, using electric arc lights, was adopted.

In Figs. 3 and 4, the outline of the object is not very clear. This is due to the fact that the camera was focused on the light beam, which was in the middle of the wind tunnel, and, therefore, the end of the object was closer to the lens. In later experiments a tapered airfoil was used, as shown in Figs. 4, 5, 6, and 7. Figs. 7 and 8 show a study of the airflow in front of and behind and airfoil.

Book Review

Airplane Design—Performance, by EDWARD P. WARNER; McGraw-Hill Book Company, New York, 1936; 653 pages, ill., $6.00.

Those who have studied the author's previous book entitled Aerodynamics of Airplane Design (1927) will concur with him that aerodynamics and airplane design have progressed so much in the last ten years as not to permit "a treatment of aerodynamics of design within a single pair of covers." The author went much farther, he did not amend his previous work and split it up into two or three volumes but rewrote and rearranged the subject matter completely. This reviewer finds that the first chapter, dealing with "Introduction and Nomenclature" is too long. Since this book is written for aeronautical engineers and students, it can be safely assumed that such readers know all the necessary terms and expressions.

To those who like mathematical gymnastics, derivations of formulas, methods of solution of equations etc., the book will be a disappointment as the author has confined his work to the purely factual side of aerodynamics, giving, however, ample references where such derivations can be obtained. This reviewer believes, however, that in some cases the author went slightly too far with this idea, especially in Chapter II dealing with "Some General Principles" and Chapter III, "General Consideration on Airfoils." In this last mentioned chapter the beauty of the Bernouli's theorem is through this simplification, unfortunately, completely lost.

Where the author's ability as a teacher reaches its height is in Chapter VI, "Boundary Layer and Skin Friction," in which the very complicated but nevertheless most important contributions of Prandtl, Kármán, Millikan, Dryden, and others are reviewed and made understandable without the use of mathematics. This chapter is written so vividly and interestingly that it will, no doubt, promote among the serious students, a desire to equip themselves with the necessary mental tools so as to be able to appreciate by studying the original contributions, the far reaching consequences of those researches. In Chapter X, "Variable-Lift Airfoil Arrangements," the author should have included a more detailed discussion of the different means to actuate the flap mechanism but perhaps he found that this problem should be treated in a book on airplane structures. This chapter is, however, very up-to-date and will be welcomed by any modern designer. Chapter XIII, "Power-Plant Characteristics and Performance," could stand a further elucidation. However, reading the book through, the reader will find most of the information he needs in the following chapters which deal with "Propellers," "Performance Curves," etc. The last chapter, XVII, "Performance by Formula and Chart," is very clearly written and the contents will be of value to the engineering executive, and a great time saver for any airplane test crew.

Like most books by this particular publisher, *Airplane Design* is extremely well illustrated, the charts and diagrams well presented. It is regrettable, however, that the paragraphs and numbers referring to formulas are not given in the decimal system.

This reviewer believes that Mr. Warner's contribution will be welcomed by the aeronautical student and teacher alike. Also, the engineer will find it helpful as a quick reference, and the general student of science will marvel at Mr. Warner's ability to present a dry subject in such a vivid way.

STEPHEN J. ZAND

A Theory for Rectangular Wings of Small Aspect Ratio

WILLIAM BOLLAY, *California Institute of Technology*

Presented at the Fluid Mechanics Session, Fifth Annual Meeting, I. Ae. S.
January 27, 1937

THE theory for flow about wings of large aspect ratio has been worked out rather completely along the lines suggested by Prandtl. This flow is of interest for the main lifting surfaces of present day airplanes. However, for some unconventional airplane wings and especially for the control surfaces of dirigibles, the lifting surfaces have generally a very small aspect ratio and the existing theories have so far been inadequate. Moreover, the dirigible as a whole exhibits very much the same behavior, at least as far as the dynamic lift is concerned, as a wing of small aspect ratio. In view of this, Th. von Kármán suggested to the author making a theoretical analysis of wings of small aspect ratio.[1]

The first step was the limiting case of a rectangular wing of zero aspect ratio, that is, finite span but infinite chord. Such a wing is hydrodynamically equivalent to a constant distribution of bound vortices whose axes lie along the span (Fig. 1). At the ends of the span these vortices separate, the flow downstream following the resultant velocity vector. The inclination of the vortices to the wing was found to be about half the angle of attack. As an approximation, in order to simplify the calculation of the induced velocities, it was assumed that the trailing vortices formed straight lines at some effective inclination to the wing. This effective inclination was taken equal to the initial angle at which the vortices separate, on the assumption that the part of the vortex nearest the wing is the most influential in inducing downwash at the wing. With this approximation, three important results were obtained for the wing of zero aspect ratio:

(1) The lift distribution is constant across the span.
(2) The downwash is constant across the span.
(3) The normal force coefficient,

$$C_N = \frac{N}{{}^1/_2\,\rho\, U^2 \cdot b} = 2\sin^2\alpha$$

where N = normal force per unit chord, ρ = density, U = free stream velocity, b = span, and α = angle of attack.

This last result is especially interesting since it seems to indicate that the wing of zero aspect ratio behaves very much like the classical Newtonian flat plate which

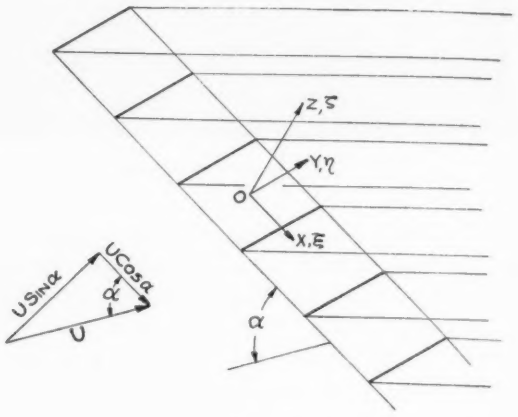


FIG. 1.

experiences a normal force proportional to the time rate of change of momentum of fluid particles hitting against it. The normal component of the velocity of these fluid particles would be $V = U \cdot \sin\alpha$, and thus if inelastic impact is assumed, one obtains as the force

$$N = \rho V \cdot V \cdot S = 2\sin^2\alpha \cdot {}^1/_2\rho\, U^2 \cdot S$$

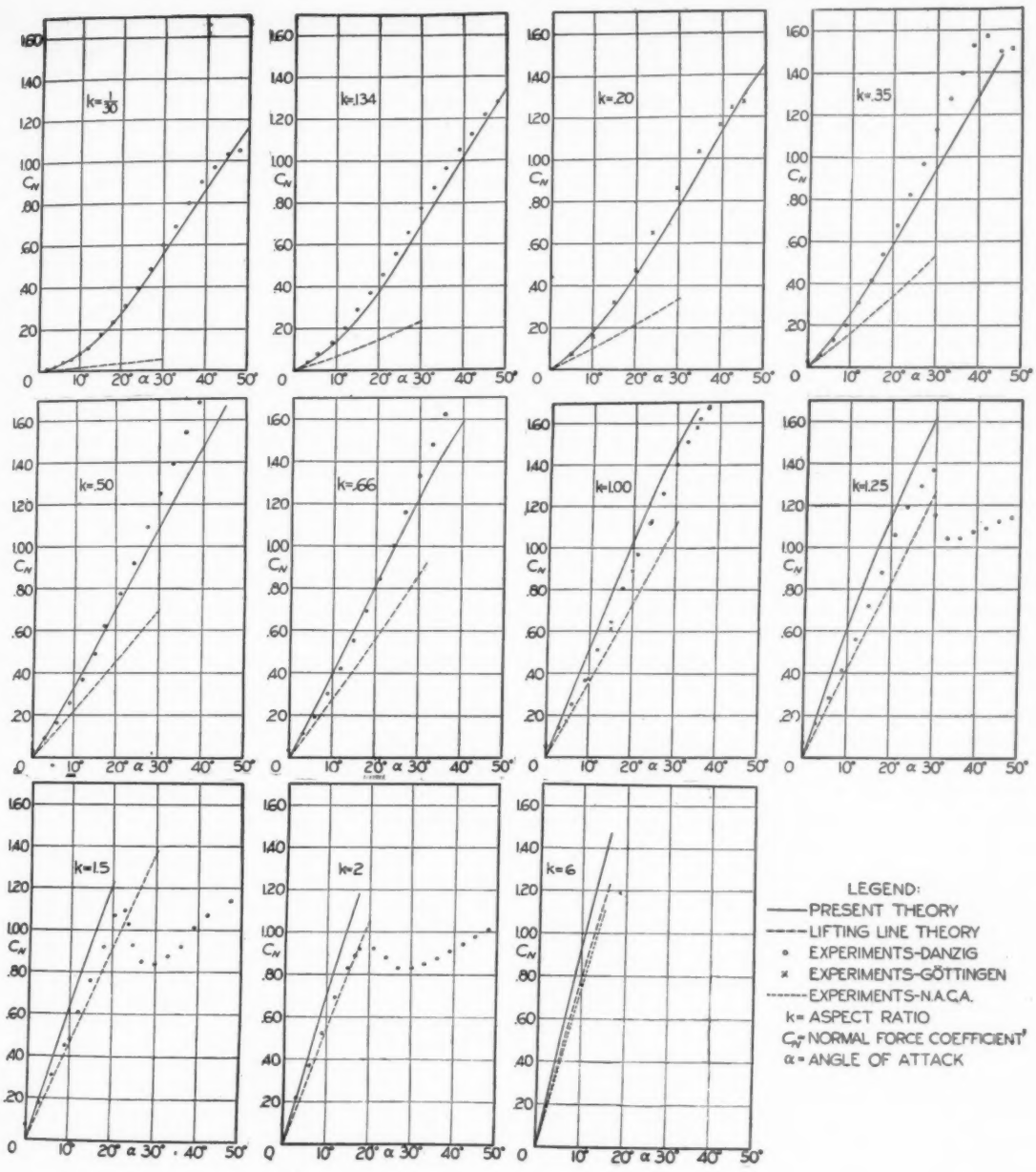
or $$C_N = 2\sin^2\alpha$$

Experiments by Winter[2] at Danzig have also shown that a $\sin^2$ law holds for wings of small aspect ratio. Flügel extrapolated the experimental values to zero aspect ratio and stated that the coefficient of $\sin^2\alpha$ is 2. Thus the present theory seems to check experimental results in this limiting case.

To extend the theory to wings of finite but small aspect ratio, it was again assumed that there was a surface distribution of bound vortices parallel to the span and that these vortices separated at the sides leaving the wing at some constant angle. The bound vortices are assumed to have a constant strength across the span. This assumption holds exactly, as has been seen, for the case of zero aspect ratio. However, it still holds well, according to experiments of Winter, at aspect ratios of about 1. At larger aspect ratios, it is known, of course, that the span distribution more nearly approaches an elliptical one and thus we would not

[1] The mathematical analysis of the above problem is shortly to be published elsewhere.

[2] H. Winter, *Forschung auf dem Gebiet des Ingenieurswesen*, Vol. 6, pp. 40–50, 67–72, 1935. Translated as N.A.C.A. Technical Memorandum 798.



expect our theory to fit exactly. At infinite aspect ratio, the elliptical distribution again goes over into a constant distribution and so this theory might again apply.

Along the chord it is assumed that the distribution of vorticity is given by a function $\gamma(x)$, where x is the coordinate along the chord. The downwash due to such a system is then calculated at the wing. The proper boundary condition would be that, at the wing, the resultant velocity is tangential, *i. e.*, the normal component of the free stream velocity U is cancelled at every point by the induced velocity. This condition shall be approximated by satisfying it along the center line of the span and assuming that as in the wing of zero aspect ratio the induced velocities are approximately constant across the span, and thus equal to the value at the middle. This boundary condition gives a rather complicated integral equation for $\gamma(x)$. Some attempts were made to solve this directly; however, a more successful method turned out to be the following: The solution of the integral equation was assumed to be of the form $\gamma(x) = \gamma_0 \sqrt{\frac{l/2 - x}{l/2 + x}}$. This is the solution which holds for the flat-plate wing of infinite aspect ratio. The constant γ_0 is then determined by substitution in the integral equation. From the total

vortex strength $\Gamma = \int_{-t/2}^{+t/2} \gamma(x) \cdot dx$, it is then an easy matter to determine the total normal force acting on the wing. The total normal force still involves the effective angle at which the vortices leave the wing. This is determined as before by finding the inclination of the resultant velocity vector at the wing tips and assuming that this inclination remains constant.

The result of this theory consists in the determination of the curve of normal force coefficient C_N *vs.* the angle of attack α. Such curves were calculated first of all for the limiting cases of zero and infinite aspect ratio. In the first case, it was found again as before that $C_N = 2 \sin^2 \alpha$. In the second case, the well-known result of the Prandtl theory was obtained, namely $C_N = C_L \cdot \cos \alpha = 2\pi \sin \alpha \cdot \cos \alpha$. For intermediate aspect ratios, the theoretical curves have been computed and compared especially with the very extensive tests made by Winter. They are shown in the series of figures ranging from $k = 1/30$ to $k = 6$. Very good agreement is obtained at the very small aspect ratios of $k = 1/30$ and $k = .134$. It is seen that at these aspect ratios the lifting line theory gives only a fraction of the total force. With increasing aspect ratio, the present theory departs more from the experiments, and the lifting line theory begins to give the initial tangent. However, even at an espect ratio of 1, the present curve gives the shape of the curve. For larger aspect ratios the lifting line theory approaches the experiments more closely. The results of the theories and experiment are shown also for $k = 6$ even though for this case some of the assumptions of the present theory break down. At infinite aspect ratios, it will be remembered both theories give the same value.

Summary

The present theory is essentially a non-linear wing theory. It differs from the conventional wing theory in the assumption that the trailing vortices leave at some angle to the wing at the place where they are formed, and thus they do not all lie in a horizontal plane passed through the trailing edge of the wing. In order to simplify the solution of the equations, assumptions were made for the lift distribution which are applicable for wings of small aspect ratio. Thus the present theory supplements the linear Prandtl theory which holds closely at large aspect ratios but becomes progressively poorer for small aspect ratios. The resulting theory correctly gives the asymptotic values of normal force coefficient for both zero and infinite aspect ratios; for the first, $C_N = 2 \sin^2 \alpha$, for the second, $C_N = 2\pi \sin \alpha \cdot \cos \alpha$. At intermediate aspect ratios, it holds well for aspect ratios less than 1; however, it gives an approximation even for the larger aspect ratios.

Book Reviews

The Conquest of the Stratosphere, by C. G. PHILP; Pitman Publishing Corporation, New York, 1937; 205 pages, $2.50.

With so much interest being taken in flight in high altitudes, this book is a welcome addition to the growing bibliography of stratospheric flight. The Institute has recently completed the first draft of such a bibliography and sent proofs to many specialists who might add to the list.

Mr. Philp devotes all of his book to the exploration of the troposphere, tropopause, and the lower regions of the stratosphere by balloons, and he has assembled much data which will be useful for the engineer who is studying the problems of flying at great heights in airplanes. A large part of the book is devoted to the scientific information which has resulted from the flights which have been made during the last ten years from the fatal ascent of Gray, to that of Major Stevens and Captain Anderson.

Each of the record flights of the Piccards, Russians, and American officers is described with an evaluation of the scientific results obtained. The assembly of this data from many sources provides a compact and progressive study of the aims and objectives of these flights.

To those who have considered such dangerous ascents as merely record-seeking achievements there will be given a new point of view. The additions to our knowledge of the cosmic rays; the many photographic experiments; the spectrographic analysis; the electrical conductivity of rarefied air; the composition of the atmosphere at great altitudes; the physiological effects and the experimentation with spores; and the employment of radio are some of the fields which have been added to with knowledge from a new source.

The author believes that 70,000 to 75,000 feet marks the probable altitude limit for the present type of balloon, but foresees the possibility of the development of new fabric and ballast which may permit greater heights to be reached.

The book is one which may be enjoyed by the layman as well as the aeronautical specialist.

I Wanted Wings, by BEIRNE LAY, JR.; Harper & Brothers, New York, 1937; 350 pages, $2.50.

The author is too modest when he writes "This is not a book for fliers." He is correct in feeling that service-trained pilots would find it merely a description of their experiences as a cadet and flying officer. But for the thousands of other pilots here and abroad, as well as all others who find flying interesting, the book will hold their interest from cover to cover. Mr. Lay's description of the requirements and training of a service pilot is vivid with emotional experiences. To the thousands of young students who are planning a career in the military or naval services it will serve as a much needed warning of the obstacles to be overcome. The chapter on aerobatics is brilliantly written but the most important part of the book and an account which will be valuable to future writers on current aviation is his description of the Air Corps participation in carrying the air mail. He titles the Chapter "They Called It Legalized Murder" and shows the point of view of a pilot who flew one of the routes from Chicago. It is well that the story has been told from the inside so that the point of view of those most concerned in the episode will be available.

There are so few writers on aeronautics that have a distinguished style that after reading this first effort any reader will hope that Mr. Lay will make further contributions to the library shelves.

Some Problems of Aviation Radio

F. X. RETTENMEYER, *RCA Manufacturing Company*

Presented at the Instruments, Radio, and Radio Meteorograph Session, Fifth Annual Meeting, I. Ae. S.

January 27, 1937

THE aviation industry has many problems to solve. Not the least of these, however, comes under the heading of Aviation Radio, for, while to many radio is a necessary evil of aviation, it has become the guiding and controlling force of the modern air transport systems and as its design features are alike in finesse to the proverbial Swiss watch, its possible ailments due to its inherent close tolerances become many. However, its ailments go beyond the more simple devices of engineering and production, going far back into the research laboratories. For example, as our modern air transport began flight through bad weather conditions involving "instrument" flying, the reported radio failures jumped alarmingly. For some time radio engineers and technicians were puzzled. For that matter, they still are, by a particular phenomenon, which for lack of a more expressive term was aeronautically called "rain," "snow," or "sand" static. Pilots began reporting, some years back, that as they entered certain overcast or cloud conditions and even when flying under or over certain of these meteorological conditions, that their radio beacon and weather broadcast receiving apparatus, and in some instances also their two-way communication high-frequency receiver equipment, first began to produce a very high and unusual sounding static response, after which it went dead. The reports were varied, greatly varied, sometimes sounding mysterious. A pilot would report that the static increased in volume along with his speed as he began a take-off, although there had been little or no static evident as he tested his equipment prior to take-off, the static increasing in frequency and volume until, as he reached cruising speed, it became almost unbearable to wear the headphones, and then suddenly the receiver apparatus became dead. In some cases the report would indicate that this condition existed throughout the flight. Other instances, however, indicated that the apparatus gradually returned to life later during the trip and worked satisfactorily throughout the remainder of the trip.

Many reports on interference with scheduled airline flight operations from this rain static condition have been to the effect that the interference was experienced during only a small portion of the flight, whereas the extreme has been a condition where no radio beacon-weather broadcast reception was possible throughout a trip.

In their efforts to determine the causes and thereafter the cure for this disturbing condition, the service technicians and the engineers obtained very discouraging data. The phenomenon of rain static would appear only under those adverse or instrument flight conditions where it was impracticable or extremely hazardous to experiment.

All of the tricks known to the radio industry for the suppression of undesired noises were tried in various ways in an effort to obtain a solution to the problem by reduction or elimination of the bothersome condition within the radio apparatus itself. None of these efforts brought about the least degree of success.

Engineering study failed to reveal any means of duplication of this phenomenon in the laboratory and being unable to simulate the condition in the laboratory, it has been difficult to deal technically with this very important situation.

However, every cloud has its silver lining. During the anxious days of investigation of this phenomenon which is now referred to as "rain static," it was remembered that a somewhat similar condition had been noticed in the operation of marine direction finder apparatus some years previous and, too, that at that time it was found that an electrostatically shielded loop antenna assisted greatly in getting around this disturbing condition.

An electrostatically shielded loop antenna as referred to here is simply a conventional loop-wound antenna around which is a complete metallic shield or housing which is broken at only one place in its periphery.

Experiments were immediately begun to determine if the same solution might apply to the aeronautical situation and while these experiments are not complete at this date, indications are that the electrostatically shielded loop antenna properly applied practically eliminates the effect of this rain static on aircraft-radio reception. The importance of the investigation and work on this particular project is seldom understood. It will be recalled that beacon lights have often been called an unnecessary luxury, for in clear weather there is no particular need for them, and in bad weather they can seldom be seen. Radio beacons, with the resulting radio beacon courses, have provided, to a marked degree, the guiding path for aircraft flight under poor visibility conditions. When the aircraft encoun-

ters conditions where the airway lights are not usable, it is confronted with a problem of navigation which revolves largely around the use of radio, especially the radio beacon system. If this same aircraft encounters meteorological conditions wherein its radio receiver apparatus becomes useless, as has usually been the case in the past whenever rain static was encountered, then the aircraft literally becomes sightless and navigation becomes entirely a problem of dead reckoning or astronomical calculations. Dead reckoning has never been applied very satisfactorily to the operation of airline aircraft and, likewise, astronomical navigation has been considered economically impractical.

The application of an electrostatically shielded loop antenna appears to offer a solution to this difficulty and the radio industry looks forward to the application of such shielded loop antennae to all aircraft, especially of the instrument flying type, believing this application offers a definite advance toward obtaining maximum usefulness of radio in aviation.

Another problem likewise presented to radio by the increase of instrument flight activity is the application of standard aircraft receiving equipment to the aircraft in such a way that the receiving system will properly indicate minimum course widths of radio beacon transmission and definitely indicate the silent zones directly over the radio beacon stations. Minimum course widths are essential to operation economy. Silent zones directly above radio beacon stations are a necessity in the safe use of the radio beacon system during the process of letting down through overcast and making instrument approaches to airports. The application of standard receiver equipment to aircraft in a manner to provide this desired result has been a most difficult one. The antenna system required to do this job most efficiently has become practically prohibitive because of the increased speed of aircraft and the consequent increased drag of such antenna. Compromises have had to be effected and, as is well known, a compromise between the desired and the most economical is rather hard to arrive at, particularly in the aviation field.

Because of the fact that a large number of the existing radio beacon stations in this country employ crossed loop type of antenna systems and the creation of silent zones above a radio beacon with minimum course widths is a function dependent upon having vertical polarization of the waves striking the antenna of the aircraft receiver system, only two types of aircraft antennae will therefore do the job satisfactorily. A mast antenna with the receiver located directly at the base provides the most favorable condition, but, as will be appreciated, presents a real drag problem and consequently an unbearable operation cost. A symmetrical "T" antenna located either above or below the aircraft, arranged with its lead-in dropping or rising vertically to the receiver equipment, provides the next best arrangement. This antenna also produces some drag effect but is by far the most economical in a cost-per-mile calculation. Either type of antenna is susceptible to the afore-mentioned rain static condition which requires the carrying of a separate electrostatically shielded loop antenna arranged preferably for rotation but at least with its plane in the line of flight, together with a switching arrangement to permit switching the radio receiving equipment to this antenna when rain static conditions make its use imperative.

In the use of a radio beacon silent zone for making approaches to airports, it will be appreciated that this method of employing the silent zone, together with a certain type of installation of equipment on the aircraft, is a negative method. Because of the ever-present deficiencies of any negative method, engineers of the U. S. Bureau of Air Commerce recently completed the basic development necessary to provide a positive indication to the aircraft of its location directly over a radio beacon. This new development presumes the use of an ultra-high-frequency marker-transmitter located on the ground at the radio beacon station with a special directive type of antenna system. The aircraft is equipped with a small, light weight, ultra-high-frequency receiver arranged to provide both aural and visual indication of the presence of the aircraft over this new type of transmitter. This new, positive "cone of silence" equipment, known as the "Z" marker, gives promise of very satisfactory application and elimination of another variable of aerial navigation and will, in addition, reduce the previously mentioned problems of radio beacon weather broadcast receiver application to the aircraft.

Another problem of large magnitude which has confronted the industry for some time has been the design of the radio beacon-weather broadcast ground station system. Some operators have wanted radio beacon signals transmitted continuously, with weather broadcasting on a separate radio frequency; others have desired operating both services on the same frequency, which, of course, has entailed cutting off the radio beacon signals during the weather broadcasts. But everyone has looked forward to the time when both services might be operated simultaneously on the same frequency, in order that the pilot might have continuous radio beacon guidance as well as weather information continuously and simultaneously available. When the method of making a low-ceiling approach or letting down through the overcast at a terminal station is reasoned out, the reasons for desiring simultaneous operation will be very apparent. The radio engineers of the U. S. Bureau of Air Commerce have just recently concluded the essential design work on a system which it is hoped will ultimately provide this desired simultaneous operation. The new system projects the use of low powered, simultaneous type radio beacon weather broadcast stations located approximately every fifty miles along all airways. The low power and close spacing has proved desirable from years of experi-

ence in order to get around the swinging and multiple courses, signal fading, etc., which has become evident from service use of the higher powered, more widely spaced stations. Also, a general feeling has grown in the industry that an airport is of little use today without radio beacon and radio telephone facilities, the contention going back to the previously mentioned light system. What good is an airport if you can't find it when flying on instruments or over the top and the only known satisfactory way of locating a field is through the use of such a radio aid?

The present development of the larger transport aircraft with which it is indicated future transcontinental service will be maintained with possibly only one stop enroute and, further, which may fly at sufficient altitude to be above all average weather conditions, has brought to radio other problems of major magnitude. This aircraft, because of the distance between its terminals, will require much greater range of communication equipment than has been heretofore, or is at present, available. The industry has begun the development of a transmitter of approximately 250 watts power output, in comparison to the present standard 50 watt equipment. This increase of power output has brought forth many problems in transmitter design, not the least of which is the provision for the most economical primary power supply. In stepping up the size of equipment, it becomes apparent that the presently used 12 volt direct current power systems of aircraft cannot be expected to furnish sufficient power at an economical rate to properly operate the proposed radio equipment. The radio load on the new super transport is, of course, only a part of the total electric load. It has been indicated that the total primary electrical load on these new ships will be approximately fifteen kilowatts. Direct current systems of the 12 volt type are obviously impractical for requirements of this type. While development of this new aircraft and its accessories has not progressed sufficiently to definitely state what its finally manufactured equipment may be, it is indicated that a 110-volt, 800-cycle a.c. power supply system will probably be used. The usage of alternating current, and especially high-frequency alternating current, has brought many problems into the design of the radio apparatus.

Increasing numbers of aircraft, airline, and airway aids have presented an acute problem with respect to the available radio channels upon which the desired or necessary communication and navigational services can be operated. This shortage of frequency channels in the portions of the radio spectrum which are now being generally used is leading the industry into many investigations of the use of ultra-high-frequencies.

Particularly pressing is the need for expansion of airport traffic control operations. At the present time there is but one frequency available for this most important service, requiring all airports of this country to operate their radio traffic control systems on this universal frequency. Low power is, of course, employed, not only because short distance communication is necessary, but also because of possible interference between closely adjacent airport stations. It is believed that the first widespread application of ultra-high-frequency communication apparatus to the aviation field will appear in this airport traffic control section, forgetting for a moment the previously mentioned use of the "Z" type of cone of silence marker for radio beacons. This appears to be an excellent place for the transition to the ultra-high-frequency portion of the spectrum to begin. Development of instrument landing systems has for some time involved the use of ultra-high-frequencies. The close tie-in of installation, operation, maintenance, etc., of instrument landing equipment with that of airport traffic control equipment brings about one encouraging aspect on the economics of the situation. It appears that a single receiver, probably of multiple purpose design, could suffice for the aircraft for usage of the "Z" markers, radio traffic control, and possibly instrument landing.

It is felt that within a reasonable number of years all of the services now operated in aviation may be expected to be conducted upon the ultra-high-frequencies. This very wide transition involves innumerable separate major projects of research and product development.

As radio advances toward its ultimate goal in aviation, just so will advance the reliability and safety of flight. Radio engineering of the magnitude involved cannot advance proportionately without the fullest cooperation of the aircraft, engine, and accessory engineering groups. There has been no shortage of such cooperation through the past, there having been an enjoyed excess, if anything, and the radio industry looks with pleasure to a continuance of this situation so as to allow the efficient and quick improvement of the present radio apparatus and to develop and apply new radio aids for aircraft navigation.

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Book Review

The Law of Civil Aviation, by N. H. MOLLER; Sweet and Maxwell, Ltd., London, 1936; 550 pages, 25s.

The Air Navigation Act of 1936 (26 Geo. V. and 1 Ed. VIII. Chap. 44) makes a resurvey of the law of England on aviation particularly timely. The author, in his preface, adverts to the difficulty of writing on a subject which is covered so extensively not only by statute but by orders and regulations which are subject to constant change. With that in view he has divided his book into two parts, the first of which concerns itself generally with the survey of the field covered by international law and by statute, leaving for part two the consideration of some of the common law bases of aviation law. Excellent appendices give the texts of such important statutes and conventions as the Air Navigation Acts of 1920 and 1936, and the Paris, the Warsaw, and the Rome Conventions.

In 1910, England, on military grounds, opposed the doctrine of the freedom of air navigation and her view triumphed in the Convention of Paris of 1919, and in similar conventions or treaties affecting air rights. Nevertheless, Mr. Moller is of the view that the doctrine of the freedom of air navigation is now desirable and ventures the opinion that with stratosphere flying in sight this doctrine will ultimately prevail (page 3). This is decidedly interesting and it is to be regretted only that the author did not amplify his views and reasons at greater length.

In part two we are met with the familiar question of the private rights in air space. The author believes (page 180) that at common law the landowner's right to the air space above his land "is a right which may be lost if not asserted"—a statement which, so far as the writer knows, is at variance with the earlier English authorities although it is in line with recent decisions in the United States. In this connection Mr. Moller (page 184) refers to the case of *Portsmouth Harbor & Hotel Co. v. United States* (1922) 260 U. S. 327, but does not refer to the later American authorities of *Smith v. New England Aircraft Company*, 269 Mass. 639; 1930 U. S. Av. R. 1; *Swetland v. Curtiss Airports Corporation*, 41 Fed. (2d.) 929; 1932 U. S. Av. R. 1; and the most recent and authoritative case of *Hinman v. Pacific Air Transport*, 84 Fed. (2d) 755; 1936 U. S. Av. R. 1, which was decided by the Circuit Court of Appeals for the Ninth Circuit in July, 1936 (certiorari denied)

It is to be hoped that in the next edition Mr. Moller will consider these authorities since, as he points out (page 189), Section 9 of the Air Navigation Act of 1936, which permits the flight of aircraft with freedom from liability for trespass or nuisance if done in such a way and with due regard to the circumstances of the case, nevertheless carries with it an absolute right to the landowner to recover damages where these conditions are not met. Thus it may well be that in a given case the English courts will again be called upon to consider the extent and nature of the liability of the aviator for aerial trespass, as well as aerial nuisance.

Chapters 6, 7, and 8 dealing with duties and liabilities of the air carrier bring under consideration the Warsaw and Rome Conventions. Particularly interesting is the description of the provisions of the Air Navigation Act of 1936 which, following the Road Traffic Acts of 1930 and 1934, enforce compulsory insurance for third party risks for all aircraft operating within the United Kingdom.

In addition to the authorities cited, Mr. Moller may be interested in considering the Scotch case of *Watson v. R.C.A. Victor Company, Inc.*, decided by the Aberdeen Sheriff's Court in 1934, 50 LL. L. R. 77; 1935 U. S. Av. R. 147, dealing with the question of salvage to foreign aircraft, and the charge of Lord Hewart, Lord Chief Justice, to a special jury, on the liability in England of the owner of a public airport found in the case of *Imperial Airways, Ltd. v. National Flying Service, Ltd.* (1932) 1933 U. S. Av. R. 50.

International flying forces the growth of international aviation law by convention, treaty, and statute. This in turn affects with a tendency toward uniformity, the domestic aviation law of the different countries of the world. If evidence be needed to show this, it will be found in the international character of the English law of civil aviation of today as it is set down in Mr. Moller's book.

HENRY S. HOTCHKISS

Institute Notes

Wright Brothers Lecture

On December 17, the thirty-fourth anniversary of the first flight by the Wright Brothers at Kitty Hawk, the Institute will inaugurate a new annual lecture to be known as the *Wright Brothers Lecture*. It will correspond to the *Wilbur Wright Memorial Lecture*, which has brought so many distinguished speakers to England. Speakers from abroad and the United States will alternate in giving the lecture.

Professor B. Melvill Jones of Cambridge University has accepted the invitation of the Institute to be the first guest speaker. Professor Jones is a member of the Aeronautical Research Committee and is the Francis Mond Professor of Aeronautical Engineering at Cambridge University. He was a pilot in the Royal Air Force during the War. He has written many papers on aeronautics and conducted research work on boundary layer phenomena for many years. The lecture will be given in the afternoon.

In the evening a dinner in honor of Professor Jones will be given at the Hotel Biltmore, New York, at which the *Sylvanus-Albert Reed Award* and the *Lawrence Sperry Award* will be presented.

Visitors to the Institute

Among the visitors to the Skyport recently have been Dr. Ing. C. H. Plock and Hans Schubert of Focke-Wulf Flugzeugbau, Bremen, Germany; Captain George Chin of the National Commission of Aviation, Shiukwan Aircraft Plant, Kwanlung, China; N. Vintcent, General Manager of Tata Sons Limited (Aviation Division) who operate airlines in India; C. O. Powis, Managing Director of Phillips and Powis Aircraft Ltd., Reading, England; Griffith Brewer of London; Commander James Bird, Supermarine Aviation, Southampton, England; Martin Wronsky, Deutsche Luft Hansa, Berlin, Germany; Karl Seyboth, Der Deutsche Sportflieger, Leipsig, Germany, and Lt. Col. J. Northcote, Melbourne, Australia.

Meeting at Dayton

At the invitation of the Commanding Officer of the Engineering Division of the Air Corps, a meeting was arranged by the Institute at Wright Field, Dayton, Ohio. Lester D. Gardner, Secretary of the Institute, presented the motion pictures of the laboratories and wind tunnels of England, Germany, and Italy. Arthur Nutt gave a lecture on *European Aviation Engines*, and Dr. Stephen J. Zand on *French and Italian Aircraft*.

The motion pictures of the English, German, and Italian aeronautical laboratories and wind tunnels have been shown or are scheduled to be shown at Philadelphia before the Aircrafters, at Wright Field, the University of Cincinnati, The Carnegie Institute of Technology at Pittsburgh, The National Research Council at Ottawa, The University of Minnesota, Purdue University, The University of Detroit, Rensselaer Polytechnic Institute at Troy, New York, and at the Georgia School of Technology at Atlanta, Georgia. The many requests for these films clearly indicate the great interest that they have aroused and each organization before which they have been shown has written expressing appreciation, not only to the Institute for loaning them, but to the governments which prepared them.

Meeting at Philadelphia

Lester D. Gardner, Secretary of the Institute, spoke at a meeting of the Aero Club of Pennsylvania at the Franklin Institute in Philadelphia on April 16. He suggested that the Institute would be interested in cooperating with local clubs and societies in holding engineering meetings. Eastman N. Jacobs and Vincent Burnelli also spoke.

Student Branches

University of Detroit. Three guest speakers were included in the program of a meeting held on Tuesday, March 23, 1937, in the Engineering building of the University.

J. J. Frey, engineer of the Ethyl Gasoline Corporation, gave a paper on *High Octane Fuels* which discussed their use in aircraft engines. He also presented a short moving picture which showed the combustion of high and low octane gasoline in an engine during operation. The head of the engine having been made of transparent material, the combustion of the engine could easily be viewed because of slow-motion pictures.

Lieutenant Kemper of the U. S. Navy Air Corps, gave a short talk on the training and advantages of the Navy Air Corps.

H. D. Copeland, manager of the Airway Traffic Control Division of the Department of Air Commerce in Detroit, spoke on *Airway Traffic Control*. An open forum was held after his talk.

University of Michigan. A meeting of this Student Branch was held on Thursday, March 18, 1937. The Chairman announced plans for an inspection trip to Wright Field, and it is expected that this trip will take place the early part of May. A short discussion was held relative to the inspection trip to the Barkley-Grow Aircraft plant and the Detroit Municipal Airport, planned for Saturday, March 20. D. C. Maier, Chief Engineer of the Barkely-Grow Aircraft Corporation, was introduced as the speaker of the evening. His talk dealt with the subject of aircraft design, paying particular attention to metal construction. Photographs of construction methods and structural tests supplemented his talk.

Another meeting of this branch was held on Thursday, April 8, 1937, in the East Engineering building of the University. Mr. Hawkins, the Chairman, announced the plans for a banquet to be held on April 29, at which T. P. Wright of the Curtiss-Wright Corporation will be guest speaker. Invitations to attend this banquet will be extended to professional members of the Institute living in the general locality. Edward I. Ryder, Instructor in Aeronautcal Engineering at the University, and now associated with Manufacturing Inspection Service of the Bureau of Air Commerce, was the guest speaker of the evening. His talk dealt with some advanced analytical treatments of columns and monocoque structures. Particular attention was paid to the behavior of metals other than steel, such as aluminum and its alloys.

Personnel Opportunities

The Personnel Bureau serves organizations seeking to employ aeronautical specialists as well as individual members. The Bureau has been the means of arranging several very successful connections for members.

Any member or organization may have requirements listed without charge.

Available

Graduate Engineer, B.S. and M.S. Theoretical and practical experience; 1 year Diesel and 3 years I.-C. Engine research, in the automotive field. Desires position in aircraft engine industry, salary optional. At present with U. S. Army in automotive work. Write Box 57, Institute of the Aeronautical Sciences.

Engineer at present employed by an airplane manufacturer, seeks a change to either research or experimental work. University mathematical training and two years practical experience in design, experimental work, and production. Specialization, performance and weight. Write Box 58, Institute of the Aeronautical Sciences.

Book Reviews

Aircraft Year Book

The Aircraft Year Book for 1937, edited by Howard Mingos; Aeronautical Chamber of Commerce of America, New York, 1937; 526 pages, ill.; $5.00 U. S. and Canada, $6.00 elsewhere.

Howard Mingos has again collected, edited, rewritten, and picturized the American aeronautical data of 1936 and presented it as a coherent whole with great skill in the Nineteenth Edition of the Aeronautical Chamber of Commerce's Year Book. With the support of government departments having to do with aeronautics and the units that comprise the aircraft industry, this book, while not a technical book, is technically accurate.

Its 526 pages embrace 200 halftone illustrations, 125 drawings of airplanes and engines and 15 chapters on the important, significant phases of aviation today. Here one will find a comprehensive analysis of the present trend in aviation, a forecast of developments during 1937, the complete story of aviation in the United States, The Army Air Corps, Air Forces of the Navy, The Flying Coast Guard, Governmental Activities in Aeronautics, State Aviation, Air Lines of the United States, Notable Flights, Private Flying, Aerial Service Operations, Airways and Airports, Education and Training, New Things in the Air—the story of aircraft engineering and manufacturing.

The principal controversial material in the book is to be found in the chapter "Air Powers of the World." Here an attempt is made to estimate the number of "armed" aircraft, including reserves and secondary reserves. Several other estimates have appeared recently showing such great differences of American opinion on this particular subject that they may evoke amused skepticism on the part of our foreign friends. So that the figures may be compared, they are given here in a combined table. "Aviation" magazine, in its issue of April, 1937, prints a chart which it admits is "a series of guesses, a probable batting order." The first estimate is a "total for military aircraft of all types" which would be comparable to the Year Book estimates. The second estimates are of "first-line aircraft." The Bendix Aviation Export Corporation estimate, published in February, 1937, analyzes the 62,000 airplanes now in use in 56 countries, of which two-thirds are claimed to be military types. An estimate of 28,500 new airplanes to be built in 1937 is made, four-fifths of which will be military aircraft.

The conclusion which is drawn from these tables by the public is usually erroneous owing to the failure to give careful consideration to the qualifying comment. The position of the United States in world aeronautics is depreciated in the minds of the public by the comparisons. We have two great oceans to protect us from air invasion and require excellence in performance rather than the enormous fleets of bombers, interceptors, and troop carriers that are needed in Europe. The whole world grants that our air transport is first in volume and technical excellence; that our naval aviation leads the world; that our research laboratories and wind tunnels are unexcelled; that our educational institutions lead in numbers of aeronautical students and excellence of training; that American types of aircraft, aircraft engines, and accessories of all kinds are licensed or copied all over the world; that we lead in airport development work; that our aircraft factories excel in their equipment and methods—and yet with all these superlative advantages, the impression is given that we are lagging behind in aeronautical development.

Air power is not to be judged solely by numbers of airplanes or aircraft. Production facilities, numbers of active, reserve, and civilian pilots, strategic location and numbers of airports, aircraft carriers and warships equipped to carry aircraft, anti-aircraft defenses, natural resources for replacements—all those enter into the comparisons. Even comparing the numbers of aircraft is difficult if not impossible. Each country needs specialized types for its defense. Without knowing the horsepower of the engines and the weights and performances of the types, the mere numbers are not sufficient to give more than the roughest idea of strength in the air.

Everyone should urge that the government should keep our air forces up to the strength required for a strong "offensive defense," but to single out our only deficiency and create a general impression is unfair to the other parts of the whole.

With correct foresight the Year Book sounds a warning that the great expansion of aeronautical laboratories in Europe may endanger our position of leadership in research unless adequate provision is made for a continuation of this work on a still broader scale.

The chapters on the work of aeronautics in the Army, Navy, Marine Corps, and Coast Guard bring the readers up-to-date on the recent achievements as well as the new equipment of these services. Each of the sixteen bureaus and other agencies of the Federal Government which are actively related to aeronautics provide summaries of their activities in 1936, and plans for the current year. Naturally, the Bureau of Air Commerce with its ever-expanding scope is given a major position in this part of the book. The chapter on "Notable Flights of 1936" as usual reflects great credit on the skill and daring of our pilots as well as the excellence of our flying equipment.

The growth of air transport in the United States in 1936 is shown by statistical charts and descriptions of the general development as well as the progress made by each individual air line. Aerial Service, Private Flying, Training and Education, Airways and Airports, and State Aviation Activities are given chapters which describe the advances made in each activity.

Of course, the largest portion of the book is devoted to descriptions and diagrams of the latest American airplanes and aeronautical engines. As always, each company in the industry has an opportunity to indicate on the 167 pages devoted to "New Things in the Air" some of its developments during the last year. This section is invaluable for those who wish to keep abreast of American aeronautical engineering work.

	Year Book for 1937 Estimated Combat Airplane Strength						Aviation				Bendix Military			
Country	R	1935	R	1936	R	1937	R	All Military	R	First Line	R	1936	R	End of 1937
Czechoslovakia											7	2400	8	3100
France	1	3600	2	3400	2	3600	4	4500	4	2000	1	5800	2	8300
Germany	7	600	7	1600	5	3000	2	6500	2	3500	5	2900	4	5800
Great Britain	3	2800	1	3600	1	4000	5	3500	5	1500	4	3000	5	5700
Italy	4	2300	4	2800	4	3200	3	5500	3	2800	3	3600	3	5900
Japan	6	1850	6	1800	7	2000	7	2000	7	1000	4	3000	6	5100
Poland											8	2200	9	2900
Rumania											8	2200	10	2600
U. S. S. R.	2	3000	3	3300	3	3400	1	7500	1	4500	2	5400	1	8400
Yogoslavia											9	1200	11	1740
United States	5	2060	5	1900	6	2200	6	2200	6	1200	6	2600	7	3800

"R" Columns show relative positions numerically

The appendix, which gives the statistical and personnel records of the aircraft field, is familiar to everyone who has used this annual as a desk reference book for many years. To old friends, the Year Book will be received as an expected invaluable yearly visitor. To those who see it for the first time it will be surprising in its completeness and utility.

LESTER D. GARDNER

Around the World in Eighteen Days and How To Do It, by H. R. EKINS; Longmans, Green and Co., New York, 1936; 186 pages, ill., $2.00.

Girl Around the World, by DOROTHY KILGALLEN; David McKay Company, Philadelphia; 219 pages, ill., $2.00.

These two books, which give different viewpoints of what developed into a competitive race around the world, may be reviewed together with better results than if they were considered separately.

The writer of this review had the privilege of observing the Hindenburg part of the flight and enjoying the acquaintance with Miss Kilgallen, Mr. Ekins, and Mr. Kieran. He discussed their plans with them and noted the fine spirit of friendly rivalry which they displayed.

Miss Kilgallen, who was an inexperienced traveller, had been entered in the contest at the last moment and was obviously sent to give a feminine point of view of world air travel, to parallel the Nelly Bly epic trip and to have the Hearst group of papers represented with the United Press and the New York Times and associated papers. Her charm and girlish manner covered the five years of experience she had, even at the age of 23, as a capable newspaper woman. She frankly said that she did not know definitely the route she was going to fly as arrangements had not been completed before she left on the Hindenburg. Rumors were that the Pan American Airways had refused to accept a woman passenger on a flight which was to include only newspaper men. She started on the chance that this could be arranged.

One of the impressions that they all wished to convey was that they intended to use only means of transportation that were available to air travellers who would follow. While they all made technical violations of this rule it will be quite true that unless a traveller wishes to break a record the routes they followed may be easily duplicated by any regular passenger.

Miss Kilgallen's book was evidently hurriedly prepared by her associates from her cable dispatches and contains much duplication. It is descriptive from a woman's point of view and will do much to assist a man who wishes to take such a trip to show his wife how easy and picturesque such a trip would be. For this, as well as the unsophisticated descriptions, she should be thanked by all who are interested in world air travel.

A totally different type of book has been written by Mr. Ekins. It is carefully and accurately written by an experienced newspaper writer who knew his globe and air travel. Instead of devoting much space to impressions of his ground experiences he has prepared what will be a handy guide book for round the world travellers. One of the most significant impressions that he conveys is that he selected the route flown by the Dutch airlines (K.L.M.) because he believed that American Douglas airplanes and Pratt & Whitney engines would give him greater speed than by using European equipment. Excepting his flight on the Hindenburg he found it possible to fly around the world using only American airplanes and engines. His two competitors used trains, automobiles and steamer, so that in addition to his record-making flight of eighteen and one half days, he was the first passenger to circle the globe exclusively by air. As he predicts, the record can even now be reduced to two weeks by careful planning and weather luck.

He includes a useful appendix which gives costs, time tables, and other useful information for his successors in such trips or any portion of them.

These three flights were, in the opinions of many well-informed aeronautical observers, the most useful and helpful of all the so-called record long distance flights as they minimized the thrills and the dangers and emphasized the practicability and pleasure of air travel. Apparently the wear and tear of air touring comes from the entertainment on the ground rather than from any fatigue of flying. At least this is the impression given by the two authors, which is confirmed by the experiences of the writer.

LESTER D. GARDNER

Journées Techniques Internationales de L'Aéronautique: CHAMBRE SYNDICALE DES INDUSTRIES AÉRONAUTIQUES, 1936; 4, Rue Galilee, Paris (XVI^{e}); 624 pages, 80 fr.

This volume of the proceedings of a six day scientific meeting held in Paris under the auspices of the Chambre Syndicale des Industries Aéronautiques, covers the fields of Motors and Fuels, High Altitude Flight, Corrosion, and Aerodynamics. The French specialists in each of these branches contributed papers, after which there were discussions. Even the slightest review of the six hundred odd pages would not do justice to the excellence of the papers. So that those who are interested may know the titles of the papers contained in the book, they follow:

Général Duval, *Discours d'ouvertuer;* M. Labussiére, *Les recherches scientifiques en aéronautique;* M. Lehr, *Construction et métallurgie des moteurs d'aviation;* MM. Dickinson et Neill, *Construction et métallurgie des moteurs d'aviation;* M. Carlo Bona, *Les moteurs italiens pour appareils de vol à grande vitesse;* M. Ferreti, *Les turbines à gaz d'échappement des moteurs à combustion interne;* MM. Weiss et Maillard, *Les huiles minérales de graissage pour moteurs à combustion interne;* M. Moutte, *Utilisation des carburants d'aviation. Normes et études au laboratoire;* M. Capetti, *Les méthodes d'essais des carburants employés dans l'aviation;* MM. Woog et Givaudon, *Les gommes dans les carburants;* M. Ploix, *L'essence et l'huile dans les moteurs d'aviation;* M. Bass, *Carburants à nombre d'octane élevé pour l'aviation civile;* M. Bonnier, *Quelques réflexions sur l'utilisation des combustibles;* M. Boerlage, *La détonation;* M. Henry Farman, *Vol stratosphérique et cabine étanche;* M. Rosenstiel, *Une solution au problème physiologique des hauts altitudes: le scaphandre aèrien;* M. Racine, *La suralimentation des moteurs à combustion interne;* M. Gourdou, *Barographes;* M. Caproni, *Le problème du vol stratosphérique;* M. Garsaux, *Les conditions physiologiques du vol á haute altitude;* M. W.-C. Rockefeller et M. Norton B. Moore, *Le transport aérien à haute altitude;* M. Grard, *La corrosion et l'homogénéité;* M. Legendre, *Quinze ans d'études de la corrosion;* M. Lecoeuvre, *La lutte contre la corrosion dans la construction aéronautique; état actual de la question;* M. Haus, *Essais en vol avec mesures et caractéristiques des trajectoires et mouvements;* M. Kampé de Fériet, *La turbulence atmosphérique;* M. Coroller, *Etudes comparées des stabilités en soufflerie et en vol;* M. Gourdou, *Diminution de la vitesse limite des avions par variation du pas de l'hélice;* M. Lapresle, *Valeur pratique des essais en soufflerie;* M. Toussaint, *De quelques questions d'aérotechnique;* M. Breguet, *Gyroplanes;* M. de l'Escaille, *Discours de clôture.*

Exchanges

The Institute exchanges the Journal with many other aeronautical periodicals. They are kept on file at the Skyport in Rockefeller Center, New York City, where members may read them. As readers of the Journal may wish to subscribe to some of them, a list of these periodicals with their addresses is published here. Information regarding subscription prices may be secured from the Secretary of the Institute.

Aero, Maneesikatu 2, Helsingfors, Finland.

Aero Digest, 515 Madison Ave., New York City.

Aeronautica Argentina, Velez Sarsfield 57, Cordoba, Argentina.

L'Aéronautique, 55 Quai des Grands-Augustins, Paris, France.

L'Aérophile, 7 Rue Sainte-Lazare, Paris, France.

The Aeroplane, 175 Piccadilly, London, W.1, England.

L'Aerotecnica, Via delle Coppelle 35, Rome, Italy.

Les Ailes, 77 Boulevard Malesherbes, Paris, France.

Aircraft Engineering, 2 Bloomsbury Place, London, E.C.1, England.

Air Law Review, Washington Square East, New York City.

Asas, Caixa Postal 1967, Rio de Janeiro, Brazil.

Astronautics, American Rocket Society, 31 West 86th Street, New York, N. Y.

Aviation, 330 West 42nd St., New York City.

L'Aviazione, Corso Umberto 504, Rome, Italy.

Boletin de Aeronautica Civil, Calle Azcuenga 923, Buenos Aires, Argentina.

Boletin Oficial de la Direccion General de Aeronautica, Magdalena 12, Madrid, Spain.

Bulletin du Service Technique de l'Aéronautique, 72 Chaussee de Waterloo, Rhode-Saint-Genese, Belgium.

Bulletin of the American Meteorological Society, Blue Hill Observatory, Milton, Massachusetts.

Bulletin Officiel du R.A.A., 6, Rue du Mezieres, Paris (6), France.

Bulletin Technique du Bureau Veritas, 31 Rue Henri-Rochfort, Paris (17), France.

Canadian Aviation, Journal Building, Ottawa, Canada.

Contact, Fort Lee, N. J.

Deutsche Luftwacht, Schoeneberger Ufer 46, Berlin W35, Germany.

Der Deutsche Sportflieger, Petersteinweg 19, Leipzig C1, Germany.

Les Fiches Aéronautiques, 6 Rue Galilee, Paris, France.

Flight, Dorset House, Stamford St., London, S.E.1, England.

Flugwesen, Konviktska 22, Prague 1, Czechoslovakia.

Indian Aviation, P. O. Box 2361, Calcutta, India.

Interavia, 13, Corraterie, Geneva, Switzerland.

Journal of Air Law, Northwestern University, Chicago.

Journal of the Institute of Engineers, Australia, Science House, Gloucester and Essex Sts., Sydney, N. S. W., Australia.

Journal of Research of the National Bureau of Standards, U. S. Govt. Printing Office, Washington, D. C.

Journal of the Royal Aeronautical Society, 7 Albemarle St., Piccadilly, London, W.1, England.

Journal of Scientific Instruments, 1 Lowther Gardens, Exhibition Rd., London, S.W.7, England.

Journal of the Society of Automotive Engineers, 29 West 39th St., New York City.

Letectvi, Celetna 13, Praha I, Czechoslovakia.

Luftfahrt-Forschung, Verlag Oldenbourg, Munich 1, Germany.

Die Luftreise, Lindenstr. 35, Berlin SW68, Germany.

Luftfahrt-Literaturschau, Z.W.B. bei der D.V.L., Berlin-Adlershof, Germany.

Model Airplane News, 551 Fifth Avenue, New York City.

Model Aviation, The American Academy for Model Aeronautics, 1733 RCA Building, Rockefeller Center, New York, N. Y.

Monthly Weather Review, U. S. Dept. of Agriculture, Washington, D. C.

Motor and Flying, 24 Bond St., Sydney, N. S. W., Australia.

National Aeronautic Magazine, Dupont Circle, Washington, D. C.

Official Aviation Guide, 608 S. Dearborn St., Chicago, Illinois.

The Pilot, Grand Central Air Terminal, Glendale, California.

Il Politecnico, Via Spiga 32, Milan (2/7), Italy.

Popular Aviation, 608 S. Dearborn St., Chicago, Illinois.

Proceedings of Institute of Radio Engineers, 330 W. 42nd St., New York City.

Publications Scientifiques et Techniques du Ministère de l'Air, 55 Quai des Grands-Augustins, Paris, France.

Review of Scientific Instruments, 175 Fifth Ave., New York City.

Revista de Aeronautica, Ministerio de la Guerra, Apartado 1047, Madrid, Spain.

Revue de l'Armée de l'Air, 55 Quai des Grands-Augustins, Paris, France.

Revue du Ministère de l'Air, 71 Avenue des Champs-Elysees, Paris, (8), France.

Rivista Aeronautica, Ministero dell'Aeronautica, Rome, Italy.

The Royal Air Force Quarterly, Gale & Polden Ltd., 2 Amen Corner, London, E.C.4, England.

Schweizer Aero-Revue Suisse, Gubelhangstrasse 22, Zürich-Oerlikon, Switzerland.

Soaring, 1614 Delaware Ave., Wilmington, Del.

Southern Flight, Ledger Building, Fort Worth, Texas.

Sportsman Pilot, 515 Madison Ave., New York City.

Technical News Bulletin of the National Bureau of Standards, U. S. Govt. Printing Office, Washington, D. C.

Techniczne Nowosci Lotnicze, Czerwonego Kryza 21/23 m.6, Warsaw, Poland.

Technika Vosdushnogo Flota, U1. Radio 16, Moscow 16, U. S. S. R.

La Technique Aéronautique, 2 Rue Blanche, Paris (9), France.

U. S. Air Services, Transportation Building, Washington, D. C.

Western Flying, 420 S. San Pedro St., Los Angeles, California.

Wirtschaft Technik Verkehr, Alte Jakobstr. 148/155, Berlin SW68, Germany.

Zeitschrift für angewandte Mathematik und Mechanik, Kulmstr. 1, Dresden A24, Germany.

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps.

Aerodynamics

Laminar and Turbulent Boundary Layers As Affecting Practical Aerodynamics. E. N. Jacobs. Very little is known about why, how, or when transition occurs, or, therefore, about the relative extent of the laminar and turbulent boundary layers. The situation with regard to airfoil drag is particularly serious because there is no equipment capable of studying the subject experimentally in the higher full-scale range of Reynolds number which at present are of most interest. Recent progress in flow about wing sections and unsolved problems. Brief. S.A.E. Preprint for Meeting, March 11 and 12, 1937, 3 pages.

The Physicist Gets Air Minded. C. B. Millikan. Application of physics to aeronautical problems. The discussion includes: aircraft structural problems; historical developments in the aerodynamic field in regard to drag and stability; and the problem of turbulence with special reference to nature of turbulent flow, and phenomenon of heat transfer in turbulent flows. Jour. Applied Physics, February, 1937, pages 107–116, 8 illus.

Decreased Drag of Wings at Supersonic Speeds by Means of Biplane Arrangement. O. Walchner. At supersonic speeds thin profiles are generally better aerodynamically than the thick. The thin flat plate attains the best lift-drag ratios but due to lack of stiffness is not suitable as a lifting surface. According to A. Busemann, two profiles with finite thickness can now be so associated that the forces on both profiles together in two-dimensional frictionless flow are equal to or only slightly larger than those for a thin plate. Lines of flow and waves of such double profiles, with and without angle of incidence, have been constructed and forces determined. The Prandtl-Meyer solution for flow around the edge is the basis of the calculations. Report of the Aerodynamische Versuchsanstalt Goettingen. Luftfahrtforschung, February 20, 1937, pages 55–62, 13 illus., 3 tables, 15 equations.

Review of the Annual Meeting of the Institute of Aeronautical Sciences. A. Klemin and M. Watter. The first author covers papers and discussion on general aerodynamics, structures (a plea for stainless steel and refined theory), engines, fuels, and meteorology; the second author, fluid mechanics, long-range seaplane and engine problems, airplane stability and performance, flying properties, and flight tests. Aero Digest, March, 1937, pages 24–27, 159, 5 illus.

Professor Klemin's summary and comments on papers dealing with fluid mechanics, a new method of studying air flow, stability and performance, gust research, testing of flight properties, a plea for stainless steel, refinements in structural analysis, and measurement of propeller stresses. Aircraft Engineering, March, 1937, pages 69–72, 5 illus.

Aircraft Design

Cabins for Stratosphere Planes. H. Farman. Development work on a cabin for stratosphere airplanes. Design of the pilot's cockpit, and portholes, and problems of bringing the controls into the cockpit, of regulating air pressure, and of supplying fresh air are referred to in this brief abstract of paper presented before the Aerotechnical Convention in Paris. Automotive Industries, March 13, 1937, pages 429, 431.

Range of Transatlantic Flying Boats. Range, effect of headwinds, points of merit, series of drawings, and table of characteristics for the Dornier Do-18, Blohm and Voss Ha-139, Short Empire, Bleriot Santos-Dumont, CAMS-110, Latécoere Croix-du-Sud and Lt.-de-Vaiss-Paris, Liore et Olivier H-27 and H-47, Loire 102, Glenn Martin 130, and Sikorsky S-42A. Graphs for determining the range for all possible proportions of pay load included. French translation from Flugsport. Les Ailes, March 4, 1937, pages 7–8, 2 illus., 1 table.

The Simon Wing with a Rotor Turbine. The design described consists of a rotor turbine having blades or vanes, moved mechanically, and arranged at the center of pressure. The rotor extends the entire length of the wing, taking in air on the upper surface of the wing and discharging it on the lower surface. Design tested in 1933 in the S. T. Aé. wind tunnel. Les Ailes, February 25, 1937, page 8, 4 illus.

Sliding and Swept-Back Wings. F. Weinig. At good aspect ratio curvature of the induced flow may be neglected. Certain simplifications are therefore permissible which warrant indicating the influence of wing axis form on lift distribution. Deviation of wing axis from a straight axis acts as an auxiliary flap of an otherwise uniform wing with a straight axis. For the sliding rectangular wing and for the circular-form and angular swept-back wing of constant chord, these auxiliary flaps are calculated for the case of constant lift distribution. Approximate equations are also given for the wing of any chord distribution. Report of the DVL. Luftfahrtforschung, February 20, 1937, pages 45–54, 16 illus., many equations.

Interior Finish and Arrangement of Transport Airplanes. H. O. West. Design of the cabin on sleeper airplanes in regard to berths, washrooms, galley, lighting, fabrics, windows, heating and ventilating, and design of the cockpit in regard to arrangement for a crew of three members, instrument boards, chart boards, external entrance, and equipment. S.A.E. Preprint for Meeting, March 11 to 12, 1937, 11 pages.

Next Five Years in Aviation. "Power Plants," C. F. Taylor; "Fuels," G. Edgar; "Diesel Engines," R. Chilton; "Aircraft Size and Performance," I. Sikorsky; "Aerodynamics,—Stability and Control," A. Klemin; "Airplane Aerodynamics," W. Littlewood; "Aircraft Structures," B. C. Boulton; and "Airships," C. Rosendahl. Discussion taking place at the joint meeting of the American Society of Mechanical Engineers, Society of Automotive Engineers, and the Institute of the Aeronautical Sciences. Mechanical Engineering, January, 1937, pages 35–37.

The Practical Application of Fowler Flaps. H. D. Fowler. Most promising field for the application of fowlers is the long-range transoceanic flying boat and the so-called air freighters. The discussion includes:—mechanism and weight, low wing and ground clearance longitudinal balance obtained, stress and structural considerations, a spare wing, high- versus low-drag flaps, high wing loadings, lateral control, effect of basic airplane design on flaps, and practical applications. S.A.E. Preprint for Meeting, March 11 and 12, 1937, 11 pages, 2 illus., 1 table.

Tapered Wings

Aerodynamic and Structural Features of Tapered Wings. G. V. Lachmann. The discussion covers:—Spar flange weight, mean profile drag, and skin weight as affected by taper ratio; lift distribution; mean aerodynamic chord of untwisted tapered wings; damping in roll and aileron efficiency; influence on stalling of tapered wings of twist, twist combined with change of camber, and wing-tip slots; tapered wings and longitudinal stability (analysis of pitching moment, effect of downwash, influence of wing fillets, and change of trim due to flap setting); and tapered wings with high-lift devices. Typical structural solutions for cantilever wings are included. In the long discussion E. E. Blount refers to American practice and test results. Jour. Royal Aeronautical Soc., March, 1937, pages 161–212 and (disc.) pages 213–237, 45 illus., many tables and equations.

Longitudinal Stability. J. H. Crowe. Static and dynamic stability of tapered-wing monoplanes. Method proposed for dealing with different plan forms shows effects of differently tapered high- and low-wing monoplanes and indicates terms of first importance and which may be neglected. By means of the four tabular forms for longitudinal stability calculations, fairly accurate damping factors and periods may be found for different values of lift coefficient. Aircraft Engineering, March, 1937, pages 59–68, 9 illus., 6 tables, 54 equations.

Some Notes on Tapered Wings. H. B. Irving. Effects of brake flaps, taper and "sweep" on stalling. The paper by G. V. Lachmann entitled "Aerodynamic and Structural Features of Tapered Wings" is discussed and additional data included. Many flow diagrams and lift and rolling-stability curves are given showing the effect of flaps on a parallel wing, and the effect of sweep, alteration of sweep of the trailing edge, and change of speed, elliptical wings and effect of spans on rolling stability. Aircraft Engineering, February, 1937, pages 31–36, 7 illus.

Stress Analysis and Structures

Gust Loads on Airplanes. R. V. Rhode. (See TECHNICAL DATA DIGEST, February 1 issue, page 5, for abstract of preprint.) S.A.E. Jour. (Trans.), March, 1937, pages 81–88, 18 illus., 2 tables, 4 equations.

New Results in Optical Methods for Studying Stresses. L. Foeppl. Stress conditions may now be investigated in three dimensions by means of methods described. Improvements to the methods which are taken up relate to the optical effect and the time-lens exposure of dynamic properties. The discussion includes: Principles and application of photoelasticity; selection of a type of light; determination of the greatest shearing stress; glass and synthetic resins as materials for models; three-dimensional photoelasticity; the solidification and the immersion methods of Oppel; photoelastic time-lens exposure; cinematographic process and its use with 1/48,000 second as the period of illumination; and use in tests where the bar is subjected to impact. V.D.I., February 6, 1937, pages 137–141, 4 illus.

The Calculation of Span Loadings. J. R. Crean. Distribution of lift across a span is determined by successive graphical approximations. A loading curve to be composed of a series of independent arcs whose equations are polynominals of the rth degree in x is interpreted and forms of corresponding coefficients determined. The original Jurieff approximation is deduced as a particular case ($r = 1$) and its description, together with that of an interesting graphical process for its execution due to V.A. Pobyedonostev, is introduced. Aircraft Engineering, February, 1937, pages 45–50, 12 illus., 2 tables, 15 equations.

Aircraft Accessories

Motors for Flaps—and Landing Gear Operation Are Light in Weight. Type HCA2 wing-flap motor is rated at 12 volts, 55 amp., and 0.65 hp. and operates at 3500 r.p.m. Type HCA3 motor for landing gears is rated at 12 volts, 111 amp., and 1.4 hp., and operates at 4000 r.p.m. Brief reference to special motors developed by Electric Specialty Company. Aviation, March, 1937, page 45, 1 illus.

Safety Device for High Altitude Flying. Attachment to the control column of the Potez 50, which is a safeguard against loss of consciousness by the pilot should his oxygen fail him or some other mishap occur at high altitude. Few details and illustration. Scientific American, March, 1937, pages 182–183, 1 illus.

Aircraft Manufacture

Fleetwing Welds All-Metal Planes. F. H. Colvin. Shotweld method adapted to airplane construction. Special welding machine, rollers forming V sections, and an inexpensive forming press are described. Am. Machinist, March 10, 1937, pages 205–206, 3 illus.

German Production Methods. Captain N. MacMillan. "Truly Amazing Organization found in the Henschel Factory: Real Mass-Production of Aircraft." Layout of the plant so that destruction of one unit would not affect the efficiency of the others, independence of each unit in regard to water, power, heat, lighting supplies, and canteen, sheet-metal working, vertical wing-assembly jigs in which wings are built standing on edge, and flight testing are included in the comments. (Continuation.) Flight, February 25, 1937, pages 194a–194d, 4 illus.

Aircraft Performance

The Technique of Water Flying—Seaplane Handling. D. J. Brimm, Jr. Take-off in rough and smooth water, landing, equipment of a seaplane, head mooring, and handling. Suggestions for the pilot in transferring from the handling of landplanes to seaplanes. Concluded. Aviation, March, 1937, pages 30–31, 70, 3 illus.

Aircraft

Developments in Foreign Military Aircraft. W. Pleines. The following military airplanes exhibited at the Paris Show are discussed and illustrated with photographs of the airplanes, drawings of unusual features, and tables of weights and performance: Loire 250 Cl, Nieuport 161, Morane-Saulnier 405, Mureaux 190 Cl, Koolhoven FK-55, Russian ZBK-19 and ANT-35, Hanriot 220, Potez 63, Fokker G-1, Caudron C640, Breguet 462 B4, Bloch 131 B-5, Amiot 341, Lioré et Olivier Le.H.45, Farman F222, and Bristol Blenhiem. V.D.I., January 23, 1937, pages 89–97, 49 illus., 3 tables.

For Divers Duties. Versatile new Blackburn fleet-fighter dive-bomber monoplane, ordered in quantity for the Fleet Air Arm, is powered with a 825/840-hp. Bristol Mercury IX engine. Arrangement of the tail unit is said to be the most striking feature. Photographs only, one comparing the fighter with the latest version of Vultee attack-bomber which is said to be suitable for ground strafing. Attention is called to the empennage and lower gun of the Vultee which has been ordered by China, Russia, and European and South American governments. Photographs only. Flight, February 18, 1937, pages 158, 165, 4 illus. Aeroplane, February 17, 1937, pages 187–188, 3 illus.

Aircraft for the Private Owner. Characteristics and performance for 48 American, British, and German private-owner aircraft ranging from ten seaters to the smallest two-cylinder ultra-light types. Aeroplane, March 10, 1937, pages 278–291, 43 illus., 1 table.

FRANCE

Bréguet Dorand Experimental Gyroplane. A. Frachet. Experimental gyroplane for the study of rotary wing systems. Construction, characteristics, and performance in tests. Long description. Les Ailes, March 4, 1937, page 6, 5 illus., 2 tables.

Model Experiments on the H.M.-21 at the Institute of Fluid Mechanics, Lille. Results of tests on a new model of the Mignet Pou-du-Ciel. Les Ailes, March 11, 1937, pages 13–14, 7 illus.

New Airplanes in Tests. New French military airplanes now being tested include: Marcel-Bloch 150 single-seater pursuit, Morane-Saulnier 405, No. 2 (official speed, 480 km. per hour at 4000 meters), Dewoitine 510, Potez 63 C-3 (two new Hispano-Suiza 14 ABS-9 980-hp. engines), Bréguet 462 multiplace fighter (two Gnome-Rhone 14 engines), Liore-et-Olivier 45 high-speed bomber (two Hispano-Suiza 14 AA 1100-hp engines), Caudron-Renault 720 pursuit trainer (one 4-cylinder Renault 140-hp. engines), Morane-Saulnier 430 pursuit trainer, and the Bloch-210 flying boat (two Gnome Rhone K-14 engines) transporting a 1000-kg. load with a range of 1000 km. at more than 290 km. per hour. Very brief references, in some cases a few improvements. A few commercial, racing, and sport airplanes under-going tests, among them the Caudron Typhon, also referred to. Les Ailes, March 11, 1937, page 4.

Performance of the Caudron C-712. With only 60 per cent of the power, the Caudron-Renault C-712 racing airplane attained a speed of 520 km, per hour. It is powered by a Renault 19-liter 12-cylinder inverted engine with a compression higher than in the normal type. Results of performance tests made by Delmotte at Istres. Les Ailes, February 4, 1937, page 8, 1 illus.

Technical Notes. First effect of the nationalization of the Marcel Bloch aircraft company has been the construction of a bimotored Bloch 210 with wings of wood. Brief reference. Les Ailes, February 4, 1937, page 6.

GERMANY

Henschel single-seater pursuit and dive bomber, and the Henschel Hs-122 two-place general-purpose airplane which is equipped with a Rolls-Royce Kestrel II-S and has a speed of 320 km. at 4000 meters. Photographs only. Les Ailes, February 4 and 11, 1937, page 9, 2 illus.

Heinkel He-51 Pursuit Seaplane. Equipped with a B.M.W.-VI 750-hp. engine, the biplane has a maximum speed of 330 km. per hour, and a ceiling of 7700 meters. Construction, characteristics, and performance given in long description. Les Ailes, February 18, 1937, page 6, 3 illus.

GREAT BRITIAN

Another Recruit. Dart Kitten single-seater monoplane powered by a 27-hp. Ava flat-four two-stroke engine. Design and performance. Flight, February 18, 1937, page 179, 2 illus., 1 table.

A Baby Twin. Two "buried" engines, and an ingenious turntable wing-folding system are unusual features of the two-seater Carden-Baynes Bee. Two special Carden S.P.1 40-hp. engines lying on their sides drive pusher propellers through integral extension shafts. Few details. Flight, March 11, 1937, page 237, 2 illus.

Entry of the Gladiator. Production Gloster fighter now being delivered to R.A.F. squadrons is powered by a Bristol Mercury IX 730/840-b.hp. engine giving maximum power at 14,000 ft. Two machine guns with interrupter gear are carried in side fairings of the fuselage and two are carried in "blisters" in the lower wings. Maximum speed 253 m.p.h. at 14,500 ft.; service ceiling, 35,000 ft.; time to climb to 20,000 ft., 9 minutes. Long description and structural drawings. Flight, March 4, 1937, pages 210a–210d, 11 illus.

A Two-Seater Lightweight. Hillson Praga (Praga 39-hp. aircooled two-cylinder horizontally-opposed engine) has a maximum speed of 92 m.p.h. Long description with structural drawings. Aeroplane, March 3, 1937, pages 251–253, 8 illus.

Excelsior! The Production-Type Gladiator Scales the Heights. Production Gloster Gladiators (825/840-hp. Bristol Mercury IX) now has an enclosed cockpit and is capable of 255 m.p.h. at 14,500 ft. Photograph only of the Gladiator in climb. Flight, February 18, 1937, page 170d, 1 illus. Aeroplane, February 17, 1937, page 185, 1 illus.

The Four Winds. Three types of Armstrong Whitworth Whitley heavy bomber are being built. The Whitley I has Tiger IX engines, the II uses Tiger VIII engines with two-speed superchargers, while power plants for the third model have not been definitely chosen. Brief reference. Flight, February 25, 1937, page 188.

A New Rotor Control. The "finger-light" rotor control of the Hafner A.R. III gyroplane is a direct result of suspending the blades on tension members of small diameter which can twist under relatively small torsional loads. In this way, friction is greatly reduced and the pilot's controls become as light as those of a fixed-wing aircraft. The rotor blades are attached to the head in the orthodox manner with horizontal hinges which permit the blades to flap, and vertical hinges with friction dampers for permitting the blades that slight freedom to alter their spacing.

The flying control has the effect of shifting the center of lift of the whole rotor system by causing the blades to assume an increased pitch angle at one point of their travel around the circle and a decreased pitch angle at other points. Detailed description of controls, rotor, and performance with drawing of rotor hub showing the "spider," incidence cranks on blade root, and internal piston. Flight, February 18, 1937, pages 160–162, 5 illus. Aeroplane, February 17, 1937, pages 197–198, 9 illus.

The Oxford Nose Bags. The new Airspeed Oxford (two Cheetah IX radials), intended primarily for military training, is a modified version of the Envoy in which the nose has been widened to take two pilots side by side. The machine carries a gun turret nearer the tail than in the convertible Envoy, and a prone bombing position in the nose. Brief reference. Aeroplane, February 17, 1937, page 207.

HOLLAND

Deadliest Weapon? Fokker G-1 two-place twin-engined light bomber, attack, or reconnaissance airplane. Maximum speed with two Bristol Mercury VII 800-hp. engines is 292 m.p.h. at 14,500 ft., and with Hispano-Suiza engines 280 m.p.h. at 11,480 ft. Climb at sea level is approximately 2000 ft. min., absolute ceiling 30,000 ft. and normal range with full tanks 1000 miles. As an attack plane armament consists of two 23-mm. cannons and two 7.9-mm. machine guns in the nose, and still another machine gun is carried in a fully rotable turret in the sharply pointed tail of the fuselage. Unusual features, armament, characteristics, and performance. Aviation, March, 1937, pages 33–34, 4 illus.

As It Was. Scheldemusch Dutch "safety-first" machine which crashed in England. Few details. Flight, March 11, 1937, page 241, 1 illus.

Doubly Deadly. At 14,400 ft. the new Koolhoven does about 230 m.p.h. Photographs only, one illustrating the cockpit enclosure, the rear portion of which houses a special Koolhoven machine-gun mounting. Flight, February 25, 1937, page 188, 2 illus.

ITALY

The Fiat B.R.-20 Bomber. A. Frachet. Equipped with two Fiat A-80 1000-hp. engines the bomber has a maximum speed of 440 km. per hour at 4000 meters. It is said to be the fastest of the heavy bombers and can cover 2500 km. at an average speed of 340 km. per hour with a total weight of 10,400 kg. Design, construction, characteristics, and performance are dealt with in a long description and armament referred to. Les Ailes, February 4, 1937, page 6, 2 illus.

The new Caproni Ca-135 bomber for the Italian Air Force is said to have a range of 3500 km., a ceiling of 8000 meters, and a speed of 430 km. per hour. Photograph only. Les Ailes, February 11, 1937, page 11, 1 illus.

Caproni Ca-135 High-Speed Bomber. A. Frachet. Monoplane of mixed construction and powered by two Isotta-Fraschini Asso-XI R.C. 820-hp. engines. The bomber flies at 430 km. per hour at 4500 meters, and can maintain this altitude with one engine off. Construction, characteristics, and performance. Long description. Les Ailes, February, 1937, page 6, 2 illus., 2 tables.

For Attack. Breda 65 monoplane of the Italian air force may be used as two-seater or single-seater for pursuit, interception, or bombardment and has a maximum speed of 440 km. per hour at 4000 meters. Photographs only. Les Ailes, March 4, 1937, page 1, 3 illus.

POLAND

Polish Aircraft and Engines. V. Porger. PZL 24A single-seater pursuit (900-hp. Gnôme-Rhône 14 Kfs) flies at 430 km. per hour, the PZL 23 long-distance day bomber (680-hp. PZL Pegasus) at 340 km. per hour; the RWD-8 training plane (110-hp. Walter-Junior) 175 km. per hour; the RWD-11 commercial (two Walter-Major 6 200-hp.), 300 km. per hour; and the RWD-13 sport plane (Walter-Major 4 130-hp.) 210 km. per hour. Construction, characteristics, performance. V.D.I., February 27, 1937, pages 273–275, 4 illus., 1 table.

U. S. A.

Chance Vought V.143 Single-Seater Pursuit. Characteristics and performance of airplane "tested by the Army Air Corps at Wright Field." Rev. de l'Armée de l'Air, January, 1937, pages 116–118, 4 illus.

Curtiss Wright 19-R. Two-Seater Training Plane. Characteristics and performance for the airplane both as trainer and attack plane and when powered with Wright R.760 and R.975 engines, respectively. Armament referred to. Rev. de l'Armée de l'Air, January, 1937, pages 118–120, 1 illus., 1 table.

Construction, layout of armament, characteristics, and performance. L'Aérophile, February,1937, pages 26–27, 2 illus., 3 tables.

The Four Winds. Seversky two-seater Cyclone-powered fighter with a maximum speed of 312 m.p.h. and a range of 2100 miles at 70 per cent horsepower. Range can be increased to 5000 miles with extra tankage. Brief reference. Flight, March 11, 1937, page 230.

Barkley-Grow. New six-passenger twin-engined low-wing all-metal light transport monoplane has been designed as a feeder transport, executive, or de luxe air cruiser, or as military ambulance or light bomber. Equipped with two Wasp, Jr. SB engines the airplane is expected to have a top speed of 225 m.p.h. at 5000 ft. Design, equipment, new Barkley multi-spar stressed-skin wing construction, and estimated performance with Jacobs L-5 and Wright 760-E-2 engines. Aviation, March, 1937, pages 35, 39, 1 illus.

Belt Drive Boat—With Terraplane Engine Built at Casey Jones School. Two-place pusher amphibian with automobile engine and a V belt-driven propeller built under direction of L. Warrender and W. Hartung. Details of design and results of flight tests as a flying boat. Aviation, March, 1937, page 35, 2 illus.

Boeing Begins Production of 4-Engined Transport Planes. "Fleets of four-engined Boeings now under construction will be so designed that substratosphere flying will be possible through the addition of pressure equipment for supercharging the passenger cabins. The Seattle factory is devoted exclusively to the production of four-engined aircraft. A few details of the transports. Automotive Industries, March 6, 1937, pages 380–381. U. S. Air Services, March, 1937, page 16.

The Four Winds. Brief specifications for the Vought SBU-1 scout bomber biplane as used from American aircraft carriers. Flight, February 18, 1937, page 165.

Military Airplanes. The 32 American military airplanes described are proven types available for export. Some have been in use by the U. S. Army and Naval Air Services and some in the foreign air forces. Specifications, engines, performance, construction, standard equipment, instruments, photograph, and three-view drawing are given. The last page (newest types of military aircraft) gives only the span, length, photograph and three-view drawings for the Douglas O-46A, North American O-47, Curtiss BF2C-1, Curtiss SOC-1, Consolidated PBY-1, Curtiss P-36, Curtiss A-18, and Curtiss SB C-3 airplanes. Aero Digest, March, 1937, pages 100–124 (alternate pages) many illus.

Power-Plants, Dimensions, Weights, and Performance of American Aircraft (Current Production). Data on 2 one-place, 42 two-place, 6 three-place, 5 four-place, 5 four-five-place, 12 five-place, 3 six-place, and 26 seven-place (and over) aircraft are given in a table and also in a directory of American commercial airplanes. Western Flying, March, 1937, pages 44–45, 48–97, many illus., 1 table.

Private and Commercial Airplanes. Descriptive technical digest of 77 American private and commercial aircraft. Aero Digest, March, 1937, pages 46–98 (alternate pages) many illus.

Specification and Performance Data of American Airplanes in Use But Out of Production. Two-page table of 95 types. Western Flying, March, 1937, pages 42–43, 1 table.

Lockheed Building 265 M.P.H. Transport. New twin-engined 14-place midwing monoplane with a projected top speed of 265 m.p.h. and an estimated cruising speed of 240 m.p.h. It is the first commercial landplane version of integral fuel tanks. Design, equipment, characteristics, and performance. Aviation, March, 1937, pages 39, 41, 1 illus., 3 tables.

Aircraft Vibration Measurement

Measurement of Vibration in Flight. C. S. Draper, G. P. Bentley, and H. H. Willis. M.I.T.-Sperry apparatus described consists of a number of electrical pickup units operating a central amplifying and recording unit. The recorder is a double-element photographic oscillograph. Each pickup is especially adapted to the type of vibration it is intended to measure and is so small that it does not appreciably affect the vibration characteristics of the member to which it is rigidly attached.

Flight-test installation, sample records and results, measurement of vibratory strains, pickup units, strain gage, amplifier, oscillograph, and calibrator are described. Research carried out by the Bureau of Aeronautics, and M.I.T. with the help of the Sperry Gyroscope Company. S.A.E. Preprint of Meeting, March 11 to 12, 1937, 24 pages, 14 illus.

Aircraft Accessories

About the Lockheed Works. Lockheed hydraulic controls applied to most movable parts of an airplane. Schematic sketch. Aeroplane, March 3, 1937, pages 263–264, 4 illus.

Modern Landing Gears. G. Goldman. Shock absorbers, wheels, brakes, brake control, and retractable undercarriages. Interesting features of landing gears displayed at the Paris Aircraft Show. Drawings and photographs. La Technique Aéronautique, No. 142, 1936, pages 306–320, 19 illus.

Airships

11 Year Performance Summary and Characteristics of Goodyear Non-Rigid Airships, June 3, 1925 to June 3, 1936. Two tables of statistics. Airship, January–March, 1937, page 52.

New Airship Design. Lighter-than-air ships radically different from the conventional Zeppelin are to be constructed by the Virginia Airship Company. The radical change is a tube through the center of the gas bag from bow to stern. The craft will be propelled by means of suction through this tube with motors and propellers at each end. An air speed of 125 m.p.h. for cruising and a payload of 40 passengers and 10 tons of freight are claimed. U. S. Naval Inst. Proc., March, 1937, pages 435–436.

Air Transportation

We Lead the Way. S. P. Johnston. "Except for operations that are now using American-built airplanes, the flying equipment in use in Europe today is either obsolete, or suffers from too close relationship to military types. . . . . Our operating technique is far and a way ahead of anything of its kind in the world."

Superiority of our airlines and equipment to those in Europe are pointed out and observations on European operations are given. Imperial Airways new airplanes are considered up to date, but are not in operation as yet. Aviation, March, 1937, pages 17–19, 75, 5 illus.

Cooperation for Safety. Eleven immediate steps to be taken and further cooperative studies on three more phases of the problem of safety, recommended at the Airline Safety Conference in Washington, February 4–6. Aviation, March 1937, pages 46, 49.

The Set-Up for Trans-Pacific Operation. Abstract of paper by C. H. Schildhauer entitled "Operating Problems of Flying Boats. (See TECHNICAL DATA DIGEST, December 15, 1936, page 8 for abstract of preprint.) S.A.E. Jour. (Trans.), March, 1937, page 98.

Propellers

Airscrew at the Paris Show. B. Jablousky. Gnôme-Rhône propellers are considered as the best mechanically-operated variable-pitch propellers on the French market. The different types and the fully-automatic variable-pitch propeller of deLevaud are described. The latter demonstrates the idea of pitch-adjustment attained solely by the influences of thrust and centrifugal force acting directly on the blades. Drawings include the Gnôme-Rhône pitch indicator, semi-automatic Gnôme-Rhône propeller, the Chauvière variable-pitch and Gnôme-Rhône controllable-pitch in which the pitch of the blades is set by counterweights. Aeroplane, Aeronautical Engg. Sup., February 17, 1937, pages 193–195, 4 illus.

Arc-Bladed Props—Introduced at Show by Maynard-di Cesare. Blades of all four types of this propeller are a decided arc. Three of the four types, namely, the automatic, the constant-speed, and the adjustable-pitch, have the blades offset at the hub and the fourth, known as the turbine type, has its blades set in the customary manner, but is otherwise unconventional. A few details of these propellers exhibited at the New York Show. Aviation, March, 1937, page 45, 1 illus.

The Vibration Problem in Propeller Designing. F. W. Caldwell. The discussion includes: sources of excitation; damping; experimental investigations of the Hamilton Standard Propeller Company, the DVL, Wright Field, and Bureau of Standards; methods of measuring stress; the approximate effect on fatigue strength of steel, aluminum and magnesium alloys of the presence of notches of various proportions (reported by J. B. Johnson); and the probable trend of future development. S.A.E. Preprint for Meeting, March 11 and 12, 1937, 17 pages, 14 illus., 2 tables.

The One Blade Prop. Propeller having only one blade and balanced by a counterweight on the opposite side of the hub equal to the weight of the blade. U. S. invention claimed to increase airplane speed by 25 to 30 per cent and rate of climb by 33-1/3 per cent, and to eliminate vibration. Few details. Aeroplane, March 3, 1937, page 253, 1 illus.

Out of Evil Cometh Good. Differences in the Schwarz and Heine patent processes for producing propellers. Brief reference. Aeroplane, March 3, 1937, page 264.

Supreme Propellers. New Barkley-Grow aircraft propellers of cold-rolled low-carbon steel electrically welded in assembly. Sizes available. Aero Digest, March, 1937, page 38.

Offset Propeller. Maynard-Di Cesare propeller has a decided blade arc which acts to bring the point of fatigue 4 in. closer to the hub. Few details. Aero Digest, March, 1937, page 38.

Engine Design and Research

Aircraft Engine Reduction Gears. F. L. Prescott. Types successfully used, crankcase and engine-mount stresses, direction of propeller rotation, gear-tooth forms and load equalization, and propeller shaft speeds. S.A.E. Preprint for Meeting, March 11 and 12, 1937, 13 pages, 7 illus.

The Design of Metal Fins for Air-Cooled Engines. A. E. Biermann. Analysis showing the improvement in heat transfer of aluminum fins by correct proportioning of the fin, decrease of fin thickness with increase of thermal conductivity, transfer of 2-1/4 times as much heat for correctly proportioned aluminum fins as for steel fins for same weight and pressure drop, and best fin proportions for maximum heat transfer for a given pressure drop as being also good for obtaining high heat transfer for a given power expenditure. S.A.E. Preprint for Meeting, March 11 and 12, 1937, 11 pages, 10 illus.

Design Trends in French Aircraft Engines and Propellers. H. L. Brownback. "The French have been forced to develop a new technique for certain types of airplanes. . . . . these specialized power plants are, and are going to, boost military aircraft performance to the point where we will be obliged to follow or drop back in the procession which we have certainly led for the past few years." Three prototypes of high-speed 12-liter military engines to develop 500 hp. at 4000 r.p.m. (more ultimately), and having "moteur canon" are described, two being Vee type and one horizontally opposed. Tendencies in design and successful aircraft Diesels are discussed. French propellers for military aircraft are reviewed. S.A.E. Preprint for Meeting, March 11 and 12, 1937, 10 pages, 3 illus.

Determination of Ratings for Transport Aircraft Engines. R. F. Gagg. Kinds of ratings, limitations inherent in design and construction, laboratory tests to determine performance characteristics, selection of fuel and compression ratio, power ratings, fuel-consumption and detonation-performance tests, and durability proof tests. S.A.E. Preprint for Meeting, March 11 and 12, 1937, 14 pages, 11 illus.

Detonation and Stationary Gas Waves in Petrol Engines. G. D. Boerlage, J. J. Breeze, H. van Driel, and L. A. Peletier. Difference between "pink" and "knock" can be explained and related mainly to combustion-chamber characteristics. An account of the pressure investigations carried out on an L-head single-cylinder gasoline engine under severe pinking conditions with spark plugs in various positions. Engineering, March 5, 1937, pages 254–255, 11 illus.

Flexible Exhaust Valve Seats. S. D. Heron and A. L. Beall. Flexible exhaust-valve seat described apparently conforms to the valve and produces a tight seat even though the cylinder head be distorted. Apparently complete sealing of the valve was secured in a cylinder known to be subject to exhaust-valve seat distortion. S.A.E. Preprint for Meeting, March 11 and 12, 1937, 5 pages, 2 illus.

The Future of the Air-Cooled Engine. A. H. R. Fedden. The "five-year plan" in developing aircraft engines, most likely layouts, effect of 100-octane fuel, and the Diesel engine's place in the scheme of things, including probable main aircraft categories; influence of fuel; comparison of 1500 b.hp. aircooled radial engines in regard to 100 octane and compression ignition, layout from the geometric aspect; general appearance of a projected 20-cylinder 5-bank radial of 1005-cu. in. capacity, 40-in. diameter, 1450-lb. weight, and 1000-hp. output at 13,000 ft.; a projected 12-cylinder aircooled horizontally-opposed engine designed to give 1550 hp. and weighing 1.20 lb. per hp.; comparison of the world's foremost engines; relative merits of various aircooled engine layouts; compressibility effects; standardization of complete power units; installation drag of radial versus inline aircooled engines; and drawings of a controllable ducted cooling system. Placing the engine inside the wing envelop will first come into being in the smallest engine category, 750-hp. for 820 lb. which would be suitable for twin-engined civil and military aircraft. Very long abstract of Royal Aeronautical Society paper with discussion. Flight, Aircraft Engr. Sup., February 25, 1937, pages 7–14, 8 illus., 5 tables. Aeroplane, February 24, 1937, pages 223–226, 6 illus., 2 tables.

Lubricating and Cooling Problems of Aircraft Engines. W. Worth. Results of tests at the Material Division of Air Corps designs. S.A.E. Preprint for Meeting, March 11 and 12, 1937, 19 pages, 11 illus.

Next Five Years in Aviation. "Power plants," C. F. Taylor; "Fuels," G. Edgar; "Diesel Engines," R. Chilton. Discussion at joint meeting A.S.M.E., S.A.E., and I.A.S. Mechanical Engineering, January, 1937, pages 35–37.

Observations on Cylinder-Bore Wear, M. M. Roensch.

Engine-Temperature Control Factors, H. E. Winkler. Papers and long discussions. (Previously abstracted in TECHNICAL DATA DIGEST, February 1.) S.A.E. Jour. (Trans.), March, 1937, pages 89–98, 111–119, 37 illus.

Rapid Calculation of Valve Spring Forces and Estimation of the Wobbling Points—a Necessary Aid in Design and Test. H. W. Lindemann. A simple formula taking into consideration the mass forces and derivation, and measurement of valve springs. A.T.Z., January 25, 1937, pages 36–39, 4 illus., 10 equations.

Some Cooling Ribs on Combustion-Chamber Wall. M. Serruys. Results of tests with cast-iron and Alpax cylinder heads having the interior surface in the "as-cast" state and polished, and also with very thin coatings of aluminum, copper, and chromium sprayed on by the Schoop process, with and without polishing. From the antidetonating standpoint there was considerable advantage in having the inner surface of the cylinder head smooth but not perfectly polished. Abstract from Mecanique, March and April. Automotive Industries, March 13, 1937, pages 435–436, 1 illus., 2 tables.

Supercharging of Internal-Combustion Engines with Blowers Driven by Exhaust-Gas Turbines. A. J. Buechi. Operation of the Buechi exhaust-gas turboblowers and principles on which the blowers are designed with a reference to those for aircraft engines. (Preprint available.) Trans. A.S.M.E., February, 1937, pages 85–96, 21 illus., 1 table.

Air-Cooled Aero-Motors in the Next Five Years. A. W. H. Fedden. Discussion by F. R. Banks, Major F. M. Green, Major R. H. Mayo, A. E. L. Chorlton, C. P. T. Lipscomb, R. Menetrier (designer of the Potez-Lorraine flat twelve aircraft engine), B. C. Carter, J. Pontremoli, S. H. Evans, and C. M. Bater, and the author's reply. Royal Aeronautical Society paper. Concluded. Aeroplane, March 3, 1937, pages 254–255, 2 illus., 1 table.

British Standard Specifications. Calibration of carburetor jets; seamless copper tubes for oil, gasoline, gas starters, and general purposes; and brass tubes for honeycomb type radiators. Brief abstracts. Aircraft Engineering, March, 1937, page 68.

Carburetion for Long Range Flights. W. L. Losson. Carburetor incorporating a diaphragm mechanism to replace the float mechanism and developed by Wright Aeronautical Corporation. Abstract, S.A.E. paper. Automotive Industries, March 20, 1937, pages 471–475.

Compression-Ignition Engines. No compression-ignition engines are used in R.A.F. aircraft. Research work is continuing and the Air Ministry expect that a service airplane with such motors will shortly begin flight trials. German output is alleged as 90 per month and the capacity 250 per month. Brief reference. Aeroplane, March 3, 1937, page 239.

Forged Versus Cast Crankshafts. G. Goldbach. Results of some recent German tests on crankshafts. Heat Treating & Forging, March, 1937, pages 127–128, 1 table.

Engine Testing

Dynamometry. N. S. Muir. New dynamometer to measure torque transmitted from engine to propeller consists of a spring element inserted in the drive. Deflection of the spring under the transmitted torque is measured by an electrical system developed at the Royal Aircraft Establishment from the basic principle of Ford's torsiometer. One torque meter is now in use at the R.A.E. in flight tests on an engine power investigation and another is in use in the 24-ft. wind tunnel for which it was especially designed. Brief abstract of Royal Aeronautical Society paper. Flight, March 4, 1937, page 212.

High-Speed Engine Indicators. E. S. L. Beale and R. Stansfield. System for indicating cylinder pressures and motion of mechanical parts in high-speed engines, developed at the Research Department, Anglo-Iranian Oil Company, Sunbury. Tests results, methods evolved to test units of high-speed engine indicators under actual running conditions, characteristics of typical engine diagrams, rate of change diagrams, and their value, and effects of a passage between indicating unit and cylinder are discussed in the first issue. In the second—Superimposed waves of different frequencies, design of indicator passage, damping in indicator passages, long indicator passages, effects of engine vibration, experience with other types of indicating unit, pressure calibration of diagrams, and improvement of the Standard-Sunbury indicator. Engineer, February 26, and March 5, 1937, pages 240–241 and 270–273, 21 illus.

Engine Manufacture

Now—and Then. Captain N. MacMillan. Visit to the Daimler-Benz plant where engines are being built for the German air force, and to the German Air Museum. Flight, March 4, 1937, pages 202–204, 6 illus.

Engines

The 60-Hp. Lambert Engine. Four-cylinder horizontal double flat-twin French engine. Long description. Les Ailes, March 4, 1937, page 8, 3 illus.

Aircraft Engines. Specifications, construction, accessories, and photograph for 41 basic types of American aircraft engines including: the Aeronca E-113C; Allison V-1760-C6; Arrow F; Continental A-40-4 and W670; Jacobs L-4 and L-5; Kinner SC-7, R5 and R5 Series 2, C7 and B-5; Lambert (Monocoque) R-266; Leblond 70 Model 5E, 90 Model 5F, and 110 Model 7F; Lycoming R-680-B5, R-680-B6, R-680-B2, and R-680-B4; Menasco Pirate B4, C4, and C4S, Buccaneer B6 and B6S, and Super-Buccaneer C6S-4; Pratt and Whitney Twin Wasp, Twin Wasp Junior, Wasp Junior, Wasp H Series, and Hornet E Series; Ranger 6-390-D3, V-770-B3, and SGV-770-A; Warner Scarab Junior Series-50 and Scarab Series-50; and the Wright Whirlwind E Series, R-760, and R975, the Cyclone G2 Series, G100 Series, F Series, F-50 Series, F-50 Series, and the Conqueror. Aero Digest, March, 1937, pages 126–145 (alternate pages) many illus.

American Engines Classified as to Horsepower. Tables of types and directory of aircraft engines giving characteristics and performances. Western Flying, March, 1937, pages 99–113, many illus., 1 table.

Continental W 670 Series Aircraft Engine. Cross-sectional drawing and specifications. Automotive Industries, March 20, 1937, page 474, 1 illus.

Engines. Drawings, parts, characteristics, performance, charts showing power at altitudes, and fuel-consumption curves are given for the following Hispano-Suiza engines: 14 AA-00, 14 AA-02, 14 AA-04, 14 AA-06, 14 AB-00, 14 AB-02, 9Vbs, 12 Xirs, 12 Xirsi, 12 Ydrs, and 12 Y21. La Technique Aeronautique No. 142, 1936, pages 284-305, 64 illus.

A New Two-Stroke. "B" type four-cylinder aircooled two-stroke engine, and a "C" type inverted engine. Few details of new unnamed British engine undergiong tests. Flight, March 11, 1937, page 231, 1 illus.

Pratt & Whitney R-1830 BG Aircraft Engine. Cross-sectional drawing and specifications. Automotive Industries, March 20, 1937, page 473, 1 illus.

Ranger. A 24-cylinder airplane engine delivering approximately 1000 hp. and permitting the mounting of a rapid-firing cannon is under development by the Ranger Engineering Corporation, subsidiary of Fairchild. Few details. Western Flying, March, 1937, page 116.

Technical Notes. The Alfa-Romeo 126/RC 10 engine, designed for Italian commercial airplanes, developed 800 hp. at 1000 meters at 2300 r.p.m. in recent tests. Principal characteristics. Les Ailes, February 25, 1937, page 7.

Technical Notes. The new Lambert engine is a four-cylinder double flat twin giving 60 hp. at 2500 r.p.m. Few details. Les Ailes, February 4, 1937, page 7.

World's Smallest Engine Built for Model Planes. French Terrot single-cylinder vertical aircooled two-stroke engine has a piston displacement of 0.3 cu. in., a 18-mm. bore and 20-mm. stroke. Few details. Automotive Industries, March 6, 1937, page 384, 1 illus.

Bristol Pegasus Airplane Engine. Cross-sectional drawing and specifications. Automotive Industries, March 13, 1937, page 433, 1 illus.

European Aviation Engines. Arthur Nutt. British sleeve-valve aircraft engine is considered the most outstanding development. German production engines are 7 or 8 years old but factories and laboratories are impressive. England's progress has been phenomenal. Italian materials and workmanship are criticized. Engine types, factories, and equipment in Germany, Russia, Italy, France, and England. S.A.E. Preprint for Meeting, March 11–12, 1937, 11 pages.

Maya Miles. New flying test bed for the Villiers Maya engines, results obtained, and later improvements made to these four-inline aircooled engines. Flight, February 25, 1937, page 187, 4 illus.

Plane-Engine-Cannon. Fairchild is getting along with the development of its 24-cylinder H-type 1000-hp. cannon-firing military aviation engine. Two vertical 12-cylinder opposed engines are mounted side by side with separate crankshafts geared to the propeller shaft. Business Week, March 20, 1937, page 40.

Parts and Accessories

Accurate Measurement of Fuel and Oil. Precision Victory meter recently passing N.P.L. tests. Photograph only. Flight, February 18, 1937, page 181, 1 illus.

A New K.L.G. Plug. New spark plugs for high-duty aircraft engines has six earth points radially arranged to project well over the flat-topped head of the central electrode which gives a large sparking area. Aeroplane, February 24, 1937, page 237, 1 illus.

Something New in Plugs. New K.L.G. aero-engine spark plug has six platinum/iridium wire earth points of 0.020 in. in diameter and 1–8 in. in length radially arranged over a flat-headed electrode and has proved to be very successful. Few details. Flight, March 4, 1937, page 212, 1 illus.

Steam Power Plants

Steam Power and the Air Ministry. British Air Ministry has been toying with the idea of steam propulsion for airplanes. Brief reference. Aeroplane, February 17, 1937, page 198.

Fuels and Lubricants

Technical Notes. Process of "methylation" or carbonization with reaction utilizing lignites has been developed by Michot-Dupont, Audibert, and Vallette. The products act as excellent antidetonants for gasoline. A few details only. Les Ailes, February 18, 1937, page 6.

The Value of Octane Numbers in Flight. D. P. Barnard. Changes in the knocking characteristics of aviation fuels in regard to their effects upon the earning power of engines in transport airplanes. Curves show: disposable load of current land-type transport airplanes; calculated explosion pressures versus power boost and compression ratio as related to fuel octane number requirements; cruising power relative to permissible take-off power; representative earning capacities of fuels of varying octane number; changes in earning capacity per gallon of fuel used per octane number change; change in earning capacity with octane number as affected by specific fuel consumption; and effect of heat-content decrease on revenue load and earning capacity. S.A.E. Preprint for Meeting, March 11 and 12, 1937, 18 pages, 8 illus., 1 table.

Shell Manufactures 100 Octane Motor Fuels on Large Scale. Commercial production of 100-octane aviation fuel, and reference to Wright Field tests comparing 87 and 100-octane fuel and recently reported by Lt. F. D. Klein. Oil & Gas Jour., March 25, 1937, page 108, 1 illus.

Radio

Air Track. Radio blind-landing system, developed by the Bureau of Standards and improved by Washington Institute of Technology, employs a localizer beam and a curved landing beam. Ground equipment is assembled in a small automobile trailer. Aviation, March, 1937, page 42, 3 illus.

Wireless Control Experiments. "Experiments have been made in the control by wireless of torpedo-like weapons, and the Admiralty are aware of the possibilities and limitations of such devices. The Air Ministry has no information about the gliding bombs from aeroplanes, which, American reports allege, have been perfected by an American inventor and adopted by the U. S. Navy Department." Brief reference. Aeroplane, February 17, 1937, page 189.

Aero Radio Digest. TWA rotatable loop direction finder, leadless Mycalex insulating material for aircraft radio work, Harvey airport transmitter, and Lear two-way radio. Few details. Aero Digest, March, 1937, page 32, 2 illus.

Radio Equipment

60-Megacycle Teletypewriter. Rex Martin. Bureau of Air Commerce operates a 40-mile Washington-Baltimore circuit with antennas 800 ft. below line-of-sight, demonstrating the efficiency of ultra-short waves in giving static-free communication. Transmitter, terminal equipment, and possibilities in u-h-f operation. Electronics, March, 1937, pages 10–11, 3 illus.

Introduction of Bendix Radio Products. Three types of ground radio direction finders will be offered, four instrument-landing systems will be manufactured, and two other systems are in the experimental stage. Summary of radio equipment now produced and to be offered. Aero Digest, March, 1937, pages 29–30, 3 illus.

Meteorology

Regional Weather Maps. Capt. W. H. Wenstrom. Advantages of a regional weather map which was drawn on board a Douglas airliner cruising at 3000 ft., and of radiophone broadcasts. An article by W. O. J. Roberts, entitled "Hourly Regional Weather Maps for Amateur Observers" follows Bul. Am. Meteorological Soc., February, 1937, pages 41–44 and 44–46, 1 illus.

Synoptic Determination and Forecasting Significance of Cold Fronts Aloft. B. Holzman. Number of synoptic aids for determination of warm front types of occlusions and upper cold fronts. Some of the data collected at Wright Field. Results of study begun while author was meteorologist for American Airlines. Weather presenting serious icing hazard to aircraft pointed out. Monthly Weather Rev., December, 1936, pages 400–414, 13 illus.

Acoustics

"Like a Kitten" in Sound-Proofed Sleepers. H. Bruderlin. Designing for sound control on the Douglas DST sleeper airplanes. Variation of noise level at the outer surface of the cabin side wall of the DC-2 or DST fuselage, average noise level at seated head position for the pilots' compartment, skyroom and other compartments giving an average in the cabin of 79.3, ventilating system, variation of average cabin noise level with power and propeller tip speed, and frequency analysis made throughout the airplane for record and comparison are considered. Aviation, March, 1937, pages 22-23, 69, 70, 6 illus., 1 table.

Aircraft Instruments

An Auxiliary Pilot's Post for Bombers. An auxiliary system of piloting for the bomber which has been developed by L. Constantin. Les Ailes, February 18, 1937, page 7, 1 illus.

Compass Errors Explained. J. A. McGillivray. Explanation for pitching and acceleration errors in magnetic compasses. Brief. Flight, February 11, 1937, page 168.

The Principles and Practice of Automatic Control. The Siemens autopilot for aircraft is criticized in the first issue because of its mechanical and electrical complexity and weight. Both issues discuss in detail the Sperry gyro-pilot for steering ships and the first gives a graphical study of the effect of lost motion in this device. Continuation. Engineer, February 26 and March 5, 1937, pages 236–237 and 268–269, 7 illus.

Do Pilots Fake Position? One stylus of the flight recorder for airliners traces the height at all times and the other, connected to the plane's radio-beacon receiver, records when and for how long the radio beam is used. Brief reference. Scientific Am., April, 1937, page 245.

Instruments. Pioneer sensitive altimeter calibrated for an altitude of 35,000 ft., and airspeed indicator for speeds of 0 to 500 miles. Few details. Aero Digest, March, 1937, page 38, 2 illus.

The Principles and Practice of Automatic Control. Siemens autopilot for aircraft, Sperry gyro-pilot for ships, and the Henderson gyroscopic detector of angular velocity discussed in the first issue, and Minorsky automatic pilot and gyrometer for steering ships in the second. Continuation. Engineer, March 12 and 19, 1937, pages 294–295 and 322–323, 8 illus.

Telemagnetic Compass. West telemagnetic aircraft compass embodies a new method of remote compass reading and is of aperiodic type, arranged for parallel grid reading. Few details. Aero Digest, March, 1937, page 38, 1 illus.

Airport Equipment

The Electrotechnical Installation at the Rhein-Main Airport for Airplanes and Airships. W. Wegener. The electrical equipment described in the first issue includes obstruction, rotating, and boundary lights.

In the second issue—Landing floodlights, floodlights, smoke developer, wind-direction indicator, beacon to determine the height of clouds, five-current generating plants distributed over the field for electric work, compressor installation and generating plant in the airship hangar, and lighting of the hangers, shops, and administration building. E.T.Z., February 11 and 18, 1937, pages 146–149 and 175–178, 14 illus.

Work Shop on Wheels. Colossal servicing stand developed by Pan American for the Pacific Clippers is described. Two complete units were made up each capable of handling two engines. Two working levels are available and two propeller pits are built into the main floor. A special feature is the instrument test cabinet connected into the stand at ground level which permits the testing of the automatic pilot and fuel turbine systems on the aircraft without running up any of the motors. Aviation, March, 1937, pages 24–25, 4 illus.

Airport Trends. G. Dawbarn. For high-speed all-weather inter-Continental services, airports (including zoning) ten miles long by 600 yards wide with slotted graduated airscreens down both sides are visualized. Flight, March 4, 1937, pages 206–207, 1 illus.

A Course-Giving Beacon. New G.E.C. beacon from which a pilot can tell at a glance whether he is off his course and by how much. Few details. Aeroplane, March 3, 1937, page 265, 1 illus.

Pre-Fabricated Hanger. Montgomery-Beacon private-owner hanger. Few details. Aero Digest, March, 1937, page 38, 1 illus.

A Tecalemit Installation on a High-Speed Fire Truck. Fire truck equipped for fighting fires at airports. Rev. de l'Armée de l'Air, January, 1937, pages 115–116, 2 illus.

Ice Formation Prevention

Defrosting Equipment Using a Resistant Coating for Electrical Heating. G. Chamagne. The parts to be defrosted, whether of metal or fabric, are previously covered with a very fine treated covering of asbestos, on which the resistant coating is sprayed in the colloidal state. Two longitudinal metallized bands serve as conductors of the heating current. Description of patents of Rideau and Ducret with drawing of the application to the leading edge of a wing. Les Ailes, February 18, 1937, page 7, 2 illus.

Parachutes

Switlik Cub Chute. Switlik "Com-Pak" quick-attachable seat parachute specially designed for use in a Taylor Cub airplane. Few details. Aero Digest, March, 1937, page 38.

Photography

First Meeting of Aerial Photography Organized by L'Aérophile. Amateur, military, and professional winners of contest and meeting discussed. L'Aérophile, February, 1937, pages 39–40, 4 illus.

Metals

NON-FERROUS ALLOYS

Fatigue and Corrosion-Fatigue of Bronzes. H. J. Gough and D. G. Sopwith. Fatigue and corrosion-fatigue tests on four types of special bronzes to ascertain their suitability for special aircraft purposes. Very brief abstract. Institute of Metals paper and discussion. Engineer, March 19, 1937, page 330.

Largest Aircraft Parts Press Now in Use. Farrel-Birmingham hydraulic press for blanking and forming Lockheed duralumin aircraft parts. Iron Age, March 18, 1937, page 41D–42, 2 illus.

WELDING METHODS

Aircraft Spotwelding Efforts Benefit Many Industries. B. Burns. Paper and long discussions by E. W. Morris, H. E. van Thijn, C. L. Hibert, and W. C. Hutchins. (Preprint abstracted in TECHNICAL DATA DIGEST, December 15, 1936, page 22.) S.A.E. Jour. (Trans.), March, 1937, pages 99–107 and (disc.) 107–110, 17 illus.

Plastics

Plastics at Hatfield (Aircraft). E. P. King. Results of independent tests made, in compression, with standard cord-filled material and with Permali 523H, a resin-impregnated laminated beech wood, and comparison with results presented by Dr. de Bruyne in a recent paper on plastic materials for aircraft construction.

A light composite sandwich material has been produced by the author by "welding" special resin-sprayed facings onto a central low-density core which acts almost entirely as a means of support and enables the skin to develop loads about those of the ultimate strength of the material now employed. Cord reinforcement gives the strongest moldable plastic material, but, for spar flanges and struts, lightly impregnated and compressed laminated wood-fiber material are recommended. Strength-weight ratios and relative stiffness for various materials are given. The author's device for testing relative stiffness is illustrated. Aeroplane, February 17, 1937, pages 196–197, 2 illus., 3 tables.

Air Forces

The Four Winds. Thirty-six Junkers Ju.86 bombers without engines are being acquired for the Swedish Air Force by "barter." Finland has ordered a dozen German bombers. Brief references. Flight, February 25, 1937, page 188.

FRANCE

Developments in France. Supreme Air Council, Ecole de l'Air, and reorganization and expansion of the Armée de l'Air. A few notes. Aeroplane, February 17, 1937, page 190, 1 illus.

GERMANY

In search of German and Italian Aviation. Captain N. MacMillan. A flight across Europe on three regular airlines (first issue) and a visit to the German Air Ministry (second issue). Flight, February 11 and 18, 1937, pages 144a, 144d, 145–146, and 170a–170d, 15 illus.

In search of German and Italian Aviation. Captain N. MacMillan. Visit to the Richthofen Squadron with remarks on how the German Air Force of today works, plays, and rests. Continuation. Flight, March 11, 1937, pages 226–229, 8 illus.

GREAT BRITAIN

The Air Estimates. Air Estimates for 1937 amount to a total of £88,588,600 against £55,705,600 for 1936. Fleet Air Arm grant is up by nearly £1,000,000 and £29,000,000 has been allotted for aircraft and engines. Comparative figures for 1934-5-6-7 and parts of the Memorandum. Flight, March 11, 1937, pages 232–234 and 223–224 (Editorial), 1 table. Aeroplane, March 10, 1937, page 270.

Air Power and Its Employment. Air Vice-Marshal E. L. Gossage. Development of air power in Great Britian and functions of the Royal Air Force in national and Imperial defense. Continued. Aeroplane, March 3, 1937, pages 249–250, 1 illus.

Balloon Barrages. Balloon Barrage Units now being organized on an Auxiliary Air Force basis for the defense of London. Brief reference. Aeroplane, March 3, 1937, page 241.

The Four Winds. About £400,000 is to be spent on Birmingham's first air-raid precautions scheme. Between 2000 and 3000 volunteers will be required. Brief reference. Flight, March 11, 1937, page 230.

R.A.F. Aerodrome Sites and Their Cost. Sites purchased for new R.A.F. airports and airplane factories during the past two years. List of acreage and cost of each of the 25 airports. Flight, March 4, 1937, page 214. Aeroplane, March 3, 1937, page 241.

Air Control by Blockade. Air Commodore C.F.A. Portal. Air policing work, services aircraft can render the Army in transport of troops and supplies, in fire-power, and in reconnaissance, independent air action, and examples of air-force police operations in the Aden Protectorate and Quteibi operations. Long abstract of Royal United Service Institution paper including discussion. Aeroplane, February 24, 1937, pages 219–221, 1 illus. Shorter abstract. Flight, February 25, 1937, page 189.

Air's Share. Section of British White Paper on Defence Expenditures, relating to R.A.F. expansion. Aeroplane, February 24, 1937, page 212.

The Four Winds. Total value of Air Ministry contracts for the fiscal year amounted to £67,122,500 up to December 31. Brief reference. Flight, February 25, 1937, page 188.

On Wasting Material. C. G. Grey. Suggested use, as a British reserve air force, of veterans of the War of 1914–18 and of the vast numbers of private owners and pilots never in the air force and never able to go into the air force, but yet good pilots. Aeroplane, February 17, 1936, page 186.

The Shadow Factories. Terms upon which British Shadow aircraft and aero-engine manfacture schemes will operate. Aeroplane, February 24, 1937, page 211.

Strength of the Royal Air Force. Regular 53,196 men, and auxiliaries 1903 men, as of January 1. Brief reference. Aeroplane, February 24, 1937, page 216.

ITALY

The proposed Air Ministry budget for 1937–38 is 1,250,000,000 lire, and for 1936–37, 970,389,500 lire. Brief reference. Les Ailes, February 4, 1937, page 10.

Italian Aviation. Visit of General Armengaud. The second issue deals with the Italian military organization. Les Ailes, February 4 and 11, 1937, page 11.

JAPAN

Japanese Military Aviation. Japanese Air Force and Air Ministry. Few details and illustration of the 95-1 two-seater military trainer. L'Aérophile, February, 1937, page 21, 1 illus.

SWEDEN

Air and Water. The Swedish Government has ordered 32 Gloucester Gladiators for its air force. Brief reference. Engineer, March 19, 1937, page 333.

U. S. A.

Army Air Corps Wants 30,000 Officers and Men. Major General O. Westover. "A study of the aerial defense of our Eastern frontier indicates that if certain air bases were seized and occupied by an enemy air force, possessing latest air equipment, our entire industrial area with thousands of profitable targets, as well as the Panama Canal, so essential to the maneuvering of our fleet, would be vulnerable to air attack." A plea for appropriations citing increased numbers of airplanes in the services of European nations. U. S. Air Services, March, 1937, page 25.

G H Q Air Force Conducts Winter Test of Equipment in Selfridge Field Area. Participating units in the Winter maneuvers, and in the Army mass flight from Langley Field to Panama and return. U. S. Air Services, March, 1937, page 15. Aviation, March, 1937, page 56.

Our Islands Again. Report from Washington that workers with tractors and other implements have sailed for Howland Island and the comment that if a reasonable airport can really be built there the American aerial defense line across the Pacific would be extended by 1500 miles. Brief reference. Aeroplane, February 17, 1937, page 202.

Air Services. Delivery of the second Boeing bomber to the Air Corps, winter maneuvers, Reserve activity, and 1936 procurement of airplanes for the Air Corps Brief notes. Aero Digest, March, 1937, page 155.

Looking Ahead. Cy Caldwell. "In addition to that industry program, however, the United States Government should give sufficient money to the Army Air Corps or to the Navy, or both, to enable them to develop a real racing plane and engine—one considered purely as a speed laboratory product which will influence further military and naval plane and engine design. . . . . in the Air Force we seem to be headed right with our attack ships, our bombers, and our pursuits so far as the airplanes are concerned; but when we look at engines we find all our eggs in the one radial air-cooled basket. . . . . What we need, therefore, is a fast multi-engined ship with one cannon that can be sighted and controlled accurately. We need a weapon that will outrange any that the bomber can carry."

Development of racing planes, quantity of airplanes in our air forces compared with that of Japan, England, France, Italy, and Germany, development of engines for our military airplanes, and armament necessary are discussed. Aero Digest, March, 1937, pages 23, 30.

Martin Bombers Make Mass Flight to Panama. Round-trip flight of 4000 miles from Langley Field to Albrook Field completed by eight twin-engined Martin bombers. Brief reference. Aero Digest, March, 1937, page 158.

Navy Group Spans Pacific to Hawaii in "Routine Transfer" in 22 Hours Elapsed Time. Formation flight of 12 Navy twin-engined Consolidated PBY-1 patrol boats. Brief account. Aviation, March, 1937, page 56, 2 illus.

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Various Notes. Two Fairey Féroce biplanes ordered have a "moteur canon," four machine guns in the wings, and a maximum speed of 270 m.p.h. at 13,000 ft. Few details. U. S. Naval Inst. Proc., March, 1937, page 437.

Air Warfare

The Four Winds. It is rumored that plans are being made for a "blackout" of all Switzerland and cooperation of the League of Nations has been sought. Brief reference. Flight, March 11, 1937, page 230.

Letting Light Into Spanish Affairs. R. Findlay. Situation at the Eastern end of the Franco-Spanish frontier and assistance the French are said to be rendering to the Spanish Loyalist. Continuation. Aeroplane, March 3, 1937, pages 242–245.

Balloon Aprons. Military usefulness of balloon-aprons. Aeroplane, February 17, 1937, pages 191–192. Use during the world war. Airship, January-March, 1937, pages 45–46, 2 illus.

On Letting Light Into Spanish Affairs. C. G. Grey and N. Tangye. Lessons in air warfare learned during the Spanish revolution. Events leading to the revolution, necessity for infantry to follow up air attacks, lack of moral effect in bombing raids, brilliant shooting of German antiaircraft guns and absence of effective Russian or French ones, high flying of Russian bombers and ground strafing of Nationalists, Russian, French, German, and Italian bombers used, and comparison of bombs and raid tactics. To be continued. Aeroplane, February 24, 1937, pages 213–215.

Miscellaneous

Aeronautical Data. U. S. airplane and engine production, 1936 production of aircraft and aircraft engines by types, sales of aircraft parts, 7800 airplane engines produce 1,500,000 hp., 1936 aeronautical exports up 60 per cent. Statistics are given in tables under these headings. Automotive Industries, February 27, 1937, pages 288–289, 6 tables.

Earhart to Circle Globe. Around-the-world flight planned by Amelia Earhart. Outline of course to be followed. Aviation, March, 1937, page 53.

Institute Meets. An account of the January meeting of the Institute of the Aeronautical Sciences. Aviation, March, 1937, page 55.

A Sensational Journey to the Noble Hudson from the Banks of the Formerly Beautiful Ohio. A Bradley Jones account of the Annual Meeting of the Institute of the Aeronautical Sciences and the New York Aircraft Show. U. S. Air Services, March, 1937, pages 23–25.

Show Goes West. Second Annual National Pacific Aircraft and Boat Show. Manufacturers listed and diagram of the exhibition given. Aviation, March, 1937, pages 26–27, 2 illus.

Generator Regulating Systems. B. Sykes. Operating principles of the various control systems for airplane electrical generators. Aircraft Engineering, February, 1937, pages 37–40, 9 illus.

Heart Interest. Apparatus designed by Soviet Medical Aviation Department listens to the beating of a pilot's heart while he is in the air and transmits a record of it to the ground where it is reproduced on sound film. Brief reference. Aeroplane, March 3, 1937, page 240.

An Improved Circlip. Seeger Circlip (internal type) gudgeon pin fixture and (external type) for use in place of a grub screw or bolt for locating pinions and roller races. Aircraft Engineering, February, 1937, page 52, 3 illus.

Manufacturers of Accessories and Parts (Aircraft). Aero Digest, March 1937, pages 146–154.

Letter to the Editor

March 29, 1937

Dear Sir:

In response to R. T. Jones' *Letter to the Editor* in the February, 1937 issue of the Journal which refers to my recent paper in longitudinal stability, I should like to say that I agree with Mr. Jones' statement of the importance of the heavily damped "short period" oscillation, with reference to the airplane motion. In fact, I spoke upon this subject in the stability session at the last Annual Meeting of the Institute and made essentially the same remarks as does Mr. Jones relative to the conclusions reached in Technical Report No. 578. The purpose of my paper was to discuss the subject of longitudinal stability in terms familiar to the airplane designer. In this respect, it might be considered as an attempt to help in promoting within the industry, easy familiarity with airplane dynamics, and to encourage thinking in those terms.

In an introductory résumé it is impractical to discuss ideas which are at the frontier of research and whose implications are not fully understood. However, to object to the orthodox conclusions as soon as experimental data justify it, as Mr. Jones has done, is the only way progress can be made.

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